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TECHNICAL SUPPORT TO DDGX DATA BUS SPECIFICATION WORKING GROUP.(U)

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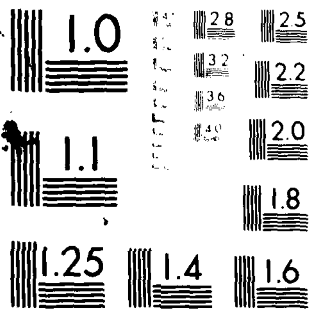

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FINAL SUMMARY REPORT
TECHNICAL SUPPORT TO DDGX DATA BUS SPECIFICATION WORKING GROUP

October 1981

Prepared for
NAVAL RESEARCH LABORATORY
WASHINGTON, D.C. 20375
under Contract N00173-79-C-0463

ARINC RESEARCH CORPORATION

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In support of the Naval Research Laboratory and Naval Sea Systems Command during the period 25 August 1980 through 30 October 1981, ARINC Research Corporation provided technical services to the Navy by serving as a member of the Data Bus Specification Working Group (DBSWG) chartered to develop a specification for the data-transfer network. This report describes the results of tasks undertaken by the DBSWG during this period.

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ABSTRACT

In support of the Naval Research Laboratory and Naval Sea Systems Command during the period 25 August 1980 through 30 October 1981, ARINC Research Corporation provided technical services to the Navy by serving as a member of the Data Bus Specification Working Group (DBSWG) chartered to develop a specification for the data-transfer network. This report describes the results of tasks undertaken by the DBSWG during this period.

FOREWORD

This final report summarizes the activities of ARINC Research Corporation in support of the Naval Research Laboratory and Naval Sea Systems Command for the period 25 August 1980 to 30 October 1981. The work was performed under Contract N00173-79-C-0463 to the Naval Research Laboratory. The report reflects the work of the entire Data Bus Specification Working Group (DBSWG). ARINC Research wishes to acknowledge the contributions made by the other organizations represented on the DBSWG: Naval Surface Weapon Center, Dahlgren; Naval Underwater Systems Center, New London; Naval Ocean Systems Center; and John Hopkins University, Applied Physics Laboratory.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Increasing emphasis is being placed on reducing the costs and improving the effectiveness of military electronic equipment. Constraints on military budgets, coupled with inflation and rising operating and support costs, are prompting a search for methods of reducing the cost of acquiring equipment and maintaining it throughout its life cycle.

Alternative techniques for the acquisition, maintenance, and support of equipment are available. One alternative is the application of commercial practices and equipment. The Department of Defense (DoD) has recently directed attention to the procurement technique of the U.S. commercial airline industry. Known as the Commercial Airline Acquisition Methodology (CAAM), this approach concentrates on technology and development planning for the procurement of aircraft avionics. Techniques of this type are of interest because they are relatively simple in comparison with military processes. They are also efficient in acquiring state-of-the-art electronic systems that offer excellent cost and reliability advantages.

The new Guided Missile Destroyer (DDGX) combat system is one program in which application of the CAAM is considered feasible and beneficial. This Navy program is developing a data bus form, fit, and function specification, including interface and protocols, for use in the DDGX combat system. There has been much discussion on the use of data buses in surface ship combat systems. The Navy is pursuing a project for a ship-signals data bus but is not yet developing a combat system data bus for digital computers and peripherals.

The combat systems of modern surface ships contain networks of computers that distribute data to various combat system elements. In the CGN-38 and CG-47 Classes, the computers are generally concentrated in one location for ease of maintenance and operation. The computer networks are "ad hoc": they join independently designed and implemented subsystems by using available tools and components, both hardware and software, and in some instances by using specially designed components (e.g., data buses, conversion sets, and switches). Data transmission is generally implemented over point-to-point wiring. A significant part of the data transmission network is used for transmitting low-data-rate status and control signals between computers

and controlled devices (launchers and radars, for example). Because the designs of subsystems and combat systems predate the current commercial and academic interest in distributive processing, they do not reflect all currently available technology.

The combat systems of major combatant ships are very complex. For this reason, they are divided into elements or subsystems (e.g., guns, radars, and missiles) to facilitate their management and to make them usable in different ship classes. This functional allocation changes slowly as changing requirements and technology mandate. For example, the Vertical Launch System (VLS) will replace a number of separate launchers used as part of anti-air, anti-surface, and anti-submarine weapon systems. The functional allocation and staggered development time makes it necessary to integrate, on a single ship, components based on different computer technologies. It also leads to conflicting goals arising from the requirement for efficient implementation of a subsystem and efficient integration of subsystems into the total ship combat system. While recent developments in computer network design may alleviate some of the difficulties, the basic problem will not be eliminated.

The integration problem is becoming more crucial because of the growing need to distribute common data (e.g., navigation data or track information), to share resources (e.g., launchers and sensors) among a variety of competing users, and to perform functions (e.g., training, test, and maintenance) that cut across established subsystem boundaries.

One current approach to alleviating this integration problem is to standardize certain common critical components, such as computers (AN/UYK-7 and AN/UYK-20 currently and AN/UYK-43 and AN/UYK-44 in the future), programming languages (CMS-2), operating systems (SDEX-20 and SDEX-7), and data transmission methods (NTDS fast channels). The details of the way in which data are communicated between subsystems and within subsystems have historically been left to subsystem designers. The existence of a distributed network of computers to carry out a given task implies an allocation of functions to various computers and other devices in the network. The design of a combat system for a ship also requires an allocation of functions to various elements. Because of the intrinsic complexity of combat systems and the large amount of existing subsystem design that must be used in any new combat system, change must be evolutionary.

The joining of a combat system's computers into a network raises a number of important issues that must be resolved in establishing an architectural philosophy for the data bus. Among these issues are system synchronization, establishment of interfaces and protocols, efficient fault tolerance, secure data transmission, sharing of common resources, partitioning of the data bus, and management of the transfer of information by the data bus.

Industry is actively pursuing independent research and development (IR&D) programs in order to obtain technical understanding of bus applications and to be prepared for procurements requiring such capability. While

many of the claims for a fully sophisticated combat system are not yet validated, it is clear that some major applications of limited scope are practical in the near future and have potentially high benefit.

1.2 APPROACH

The NAVSEA approach to developing a data transfer network for use as a tool by the DDGX combat system designers was to form a Data Bus Specification Working Group (DBSWG) that would produce the architectural description and prepare a technical specification for the data bus. The group consisted of technical personnel from Naval Surface Weapons Center (NSWC), Naval Ocean Systems Center (NOSC), Naval Underwater System Center (NUSC), Johns Hopkins University/Applied Physics Laboratory (JHU/APL), and ARINC Research Corporation. NSWC and JHU/APL cochaired the group, and ARINC Research was the Secretariat.

The objective of the working group was to develop an architectural description of a data-transfer network interface that could be used in the acquisition of subelements for the DDGX combat system. In this task detailed deliberations were to be restricted to data bus equipment interfaces, associated protocols, and bus performance that are necessary to support the DDGX and other combat system applications. The experience gained by the commercial airlines and by the Naval Air Systems Command (NAVAIR) and the Air Force in the use of MIL-STD-1553B was to be studied and applied where applicable.

ARINC Research was tasked by the Naval Research Laboratory (NRL), under Contract N00173-79-C-0463, to participate in the technical activities of the DBSWG and serve as the group's Secretariat. Two specific tasks of the DBSWG that ARINC Research was to support are as follows:

- Task One: Develop architectural philosophy for data-transfer network
- Task Two: Obtain industry coordination

In Task One, the DBSWG planned to collect engineering data concerning the projected DDGX information flow, such as data rate, message size and frequency, and acceptable delays. Existing protocol and interface standards, such as the International Standardization Organization (ISO) reference model, and various industry standards would be evaluated for use as a basis for a combat system communications reference model. In addition, the DBSWG planned to formulate a plan to attract industry interest, obtain industry comments on the architectural philosophy, and foster a competitive environment.

This report summarizes the work accomplished under the contract from 25 August 1981 to 30 October 1981. Since ARINC Research Corporation performed as part of the DBSWG, accomplishments of the entire working group are described, with emphasis on the specific role of ARINC Research as appropriate. Chapter Two describes the results of the tasks. Chapter Three presents conclusions and recommendations for future developments. Appendixes A through H present specific products prepared by the DBSWG.

CHAPTER TWO

RESULTS

This chapter summarizes the results of DBSWG efforts to develop an architectural description of a DDGX data-transfer network, with emphasis on the role played by ARINC Research Corporation. The DBSWG was cochaired by Mr. D. Green of NSWC Dahlgren and Dr. T. Sleight of JHU/APL. ARINC Research Corporation served as the DBSWG Secretariat.

2.1 TASK ONE: DEVELOP ARCHITECTURAL PHILOSOPHY FOR DATA-TRANSFER NETWORK

The activities of the DBSWG began with the first formal meeting at ARINC Research Corporation on 3 and 4 September 1980. The general charter of the working group was reviewed, and all DBSWG members made presentations providing background on their organizational experience with data buses. Splinter groups were established to conduct working sessions on specific areas. Appendix A is a report of this meeting describing the detailed discussions that took place and the working groups established. The meeting was significant since it formally established the working group and assigned splinter group responsibilities. In addition, general agreement was reached by the attendees that a layered protocol model, similar to the International Standards Organization (ISO) Open System Interconnection (OSI) reference model, should be the basis of the data-transfer network specification. Figure 2-1 depicts the OSI reference model.

Following the initial meeting, much of the work of the DBSWG was accomplished in subcommittee meetings or informal working groups. Activity was centered on the following areas:

- Program plan development
- Air Force and NAVAIR MIL-STD-1553B experience
- Foreign experience
- Reference model development
- Evaluation of Standard Information-Transfer Architecture for Combat Systems (SITACS)

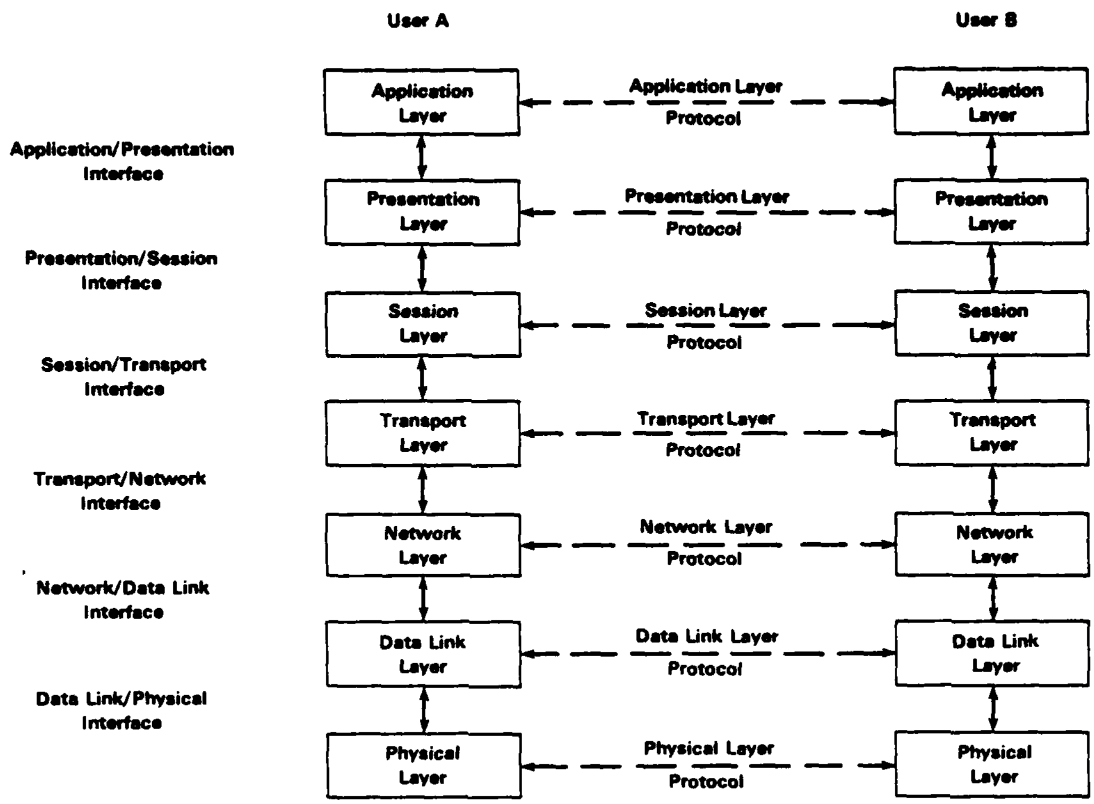

Figure 2-1. OPEN SYSTEMS INTERCONNECTION REFERENCE MODEL

These activities are discussed in the following subsections. In addition, the efforts to obtain industry comments are discussed in Section 2.2.

2.1.1 Program Plan Development

ARINC Research participated in developing a program plan to define a program for the development of an inter-computer/peripheral data-transfer mechanism specification for information transfer between combat system components by means of a shared data path, such as a data bus. The specification will be applied initially to the next-generation Guided Missile Destroyer, DDGX. Development of the plan was an iterative process, with members of the DBSWG providing comments on the draft, which were resolved and incorporated in an updated plan for further comment. The final program plan is reproduced in Appendix B.

2.1.2 Air Force and NAVAIR MIL-STD-1553B Experience

The Air Force and NAVAIR had already developed a standard (MIL-STD-1553) for multiplexing, and the DBSWG was interested in obtaining an understanding of the experience acquired in that development. For that purpose, ARINC Research attended the Air Force Systems Command Multiplex Data Bus

Conference on 17, 18, and 19 November 1980. The Air Force had documented much of its experience in the MIL-STD-1553 Multiplex Applications Handbook, which was provided to conference attendees and distributed by ARINC Research to all DBSWG members. A short discussion of the need to develop this standard is provided in the following paragraphs.

The need to increase avionics integration was first realized when requirements for missions and their associated avionic hardware could no longer be met practically with independent and self-sufficient subsystems or elements. The most frequently cited reasons for integration are space limitations; the need to eliminate unnecessary duplication of information sensing and display; and the desire to improve performance, increase reliability, and reduce costs. Integration usually began with the most complex subsystems because they had the most capability, as well as the greatest need for information from other subsystems. As digital technology progressed, central subsystems were expanded to incorporate the processing of mission-related, as opposed to subsystem-related, functions.

Problems arose early in the centralization effort because the design of subsystems was not focused on interconnection with other systems but on specialized interfaces where necessary. The input-output (I/O) circuitry of the central computer was designed to perform the function of ordering this incoming and outgoing data, with the result that I/O complexity exceeded that of the central computer. However, the concept of the central computer and its associated integration upgraded the capability of the mission and made practical the use of shared information. The solution to these centralization problems related to the complexity of the I/O was to partition and distribute the I/O circuitry, reducing the central computer's complexity. This solution was supported by trends in commercial data transfer.

Multiplexing, which makes information transfer convenient and simplifies I/O, offered the partitioning capability, and the extended computer I/O philosophy was developed. Multiplexing makes information exchange convenient because sensors and processors are all "on the bus." Multiplexing simplifies I/O because the information-transfer medium is reduced to a single wire pair. This extended I/O philosophy was adopted extensively by military avionics integrators with the development and use of military minicomputers and the availability of lower-cost digital components. These integrated avionics systems, which came to be referred to as multicomputer systems, made it possible to distribute the computation and to replace the more powerful central processor with several computers. In addition, these multiple computers added desirable redundancy features. MIL-STD-1553 and the Digital Avionic Information System (DAIS) were developed according to this integration concept.

This concept is applied in various forms today on several aircraft (e.g., B-1, F-16, F-18, and the Space Shuttle). From the subsystem equipment point of view, these approaches to integration use both integration units for unmodified subsystem interfaces (interface boxes that 1553 refers to as remote terminals) and embedded interfaces (1553 interface circuitry housed within a subsystem box). These remote terminals (RT) or

embedded 1553 interfaces connect the subsystems to the data buses. The current trend of embedding the interface in the subsystem is expected to continue.

2.1.3 Foreign Experience

A two-day meeting of representatives of the German, Canadian, and U.S. Navies was held on 3 and 4 March 1981 to address a common definition and description of a distributed architecture. Members of the DBSWG were in attendance on both days. The following topics were presented and discussed:

- DDGX Design Considerations - R. Hill
- Distributed Processing - T. Sleight/D. Green
- Shipboard Distributed Multiplex System (SDMS) - M. Wapner
- Advanced Sensor Integration Tactical Data Processing (ASI/TDP) - P. Andrews
- Low-Level Serial - R. Kolb
- Standard Information Transfer Architecture for Combat Systems (SITACS) - R. Fastring
- Shipboard Integrated Processing and Display System (SHINPADS) - CDR. J. Carruthers (CN)
- Fiber Optic Communication Network (FOCON) - German team

Appendix C presents the minutes of the meeting. It provides details of the discussions held and results of the work group sessions held on the second day. No new positions were developed, but arrangements for future data exchange were made.

2.1.4 Reference Model Development

A reference model for data-transfer systems to be used in Navy surface combat systems was developed by the Reference Model Subcommittee of the DBSWG. The model focused on projected Navy combat system requirements, particularly DDGX requirements, and was to serve as the following:

- A foundation from which data-transfer systems could be specified
- An organizing construct in describing data-transfer mechanisms
- A basis for comparison of existing and future systems

Appendix D reproduces the draft of the reference model developed by the subcommittee, which was designated as Modelman. The basic model consists of five layers, which are defined in Appendix D. The intent of the DBSWG is that these definitions constitute a set of mandatory requirements that candidate data-transfer systems must meet. In developing candidate approaches in the future, it is anticipated that developers will define characteristic features and functions of each layer. In this way a communications framework will be formed that will establish the nature

of a particular system's layers and serve as a foundation for further development of each candidate system. Appendix E describes representative functions by layer, and Appendix F presents hardware implementation examples for the Modelman reference model.

2.1.5 SITACS Evaluation

The DBSWG evaluated a plan by SEA-61 to develop a standard information-transfer system architecture plan that would (1) guide the specification and design of an overall interconnection architecture, (2) define the physical/electrical interface and communications protocols needed for subsystem acquisition planning, and (3) produce a CFE/GFE development specification to support the procurement of subsystems with embedded terminals or stand-alone terminals to be used by equipments that have standard Low-Level Serial (LLS) interfaces.

Comments were provided by DBSWG members and consolidated by ARINC Research. The consensus of the DBSWG was that the SITACS approach, while feasible, was only one specific implementation scheme that could satisfy DDGX data-transfer requirements. As such, it was recommended that SITACS be included as one of the alternative technical approaches (strawmen) discussed in Appendix B. Additional, detailed comments are provided in Appendix G.

2.2 TASK TWO: OBTAIN INDUSTRY COORDINATION

A key requirement in the development of a data-transfer network specification was to obtain industry review and comment on strawman specifications and, subsequently, on draft and final specifications. In preparation for the development of strawmen, the Navy desired to perform a number of producibility studies by industry data bus designers and manufacturers. Studies to be performed included, but were not necessarily limited to, the following:

- Conduct parametric analysis of the cost of building and maintaining serial receiver/transmitter interfaces
- Prepare engineering estimates of the cost to design, build, test, and maintain data bus terminals
- Perform parametric analysis, using a suitable model, of the impact of different bus access techniques on bus access time and message queue size
- Review and analyze data bus specifications for producibility, completeness, operational suitability, survivability, extensibility, and flexibility
- Utilize the data bus specifications and a description of the DDGX combat system to show how a distributed version of the DDGX could be designed

- Develop estimated costs of generating any required operating system software, error detection, and correction systems, and support hardware or software required for DDGX
- Determine a suitable formal specification language and use it to encode one version of the specification

A synopsis of the proposed procurement appeared in the Commerce Business Daily on 11 December 1980. A number of responses were received from industry as a result of the announcement. Firms submitting letters of interest in performing data busing producibility studies are listed in Appendix H.

CHAPTER THREE

CONCLUSIONS AND RECOMMENDATIONS

3.1 CONCLUSIONS

In conducting investigations of data-transfer requirements for the DDGX, the DBSWG reached a number of conclusions regarding the application of data-transfer networks for DDGX and future ships. Since the DBSWG is a committee formed of members who do not necessarily share identical views, a specific set of conclusions was not achieved. However, the analyses conducted by the DBSWG resulted in the following general observations:

- Data busing has already begun in Navy combat systems at the element level as program managers procure subsystems with data buses embedded in the design.
- The results of this trend toward data busing could result in a proliferation of nonstandard proprietary data buses as part of future combat systems.
- A layered communications model similar to the ISO model should be developed for Navy combat systems inter-computer/peripheral communications.
- Efforts to apply a data-transfer network to the DDGX should continue.
- Planning for data-transfer networks for future ship classes should begin now so that the scheduling problems that so frequently occur can be avoided.

On the basis of more than a year's participation in DBSWG efforts, ARINC Research Corporation believes that the issues associated with data-transfer networks for Navy combat systems have serious implications for both DDGX and future ship design. In particular, the growth of data buses at the subsystem and element levels threatens to cause a broad proliferation of nonstandard and proprietary data-transfer networks for Navy combat systems, with each network having its own architecture, interfaces, and logistics requirements. This could result in the need to develop specific interface equipment to achieve communication between data transfer networks. In addition, severe logistics problems could arise because of the need to support all of the data-transfer networks in the Fleet.

3.2 ARINC RESEARCH CORPORATION RECOMMENDATIONS

ARINC Research recommends that the development of data-transfer network specifications be pursued for both DDGX Class ships and the SSES program. The SSES program is currently being pursued by NAVSEA to achieve physical and functional separation of the platform, hull, and payload elements through the development of engineering standards that allow the design and construction of the platform to take place independently of the combat system elements. Appendix B is a program plan for developing the specifications for both programs, particularly the DDGX. In addition, under a separate contract to NAVSEA, ARINC Research and NUSC have begun to prepare a plan for developing SSES engineering standards for data-transfer networks. ARINC Research recommends that data-transfer network engineering standards be developed for SSES ships to support the SSES program objective of decoupling the payload (system) from the platform (ship).

APPENDIX A

MEETING REPORT:
DATA BUS SPECIFICATION WORKING GROUP

3-4 September 1980

This appendix reproduces the report of the first meeting of the Data Bus Specification Working Group. Because of their volume, enclosures (2) through (17) of the meeting report are not reproduced.

September 8, 1980

MEETING REPORT

SUBJECT: Data Bus Specification Working Group Meeting No. 1

DATE: September 3-4, 1980

LOCATION: ARINC Research, Annapolis, Md.

ATTENDEES: See Enclosure (1)

ENCLOSURES:
(1) Attendees
(2) Agenda
(3) Combat System Data Bus Interface Specification (Prelim)
(4) DDGX Overview
(5) DDGX (3A) Notional Combat System Configuration Alternates
(6) NSWC Presentation by Dan Green
(7) APL Presentation by Tom Sleight
(8) NOSC Presentation by Dale Bowman
(9) NOSC Presentation by Bob Reed
(10) NUSC Presentation by Chuck Arnold/Dave Watson
(11) ARINC Presentation by Chuck Lacijan
(12) NSWC Specification Viewpoints
(13) APL Specification Viewpoints
(14) Specificity of Existing Data Bus Systems
(15) Interconnection Architecture Model Report, BGS Systems Inc., September 1979
(16) Functional Requirements for Interfacing with Local Area Networks
(17) Proposed BOA Statement of Work

1. This report contains the working notes of the September 3-4, 1980 meeting of the Data Bus Specification Working Group, and is intended for internal working group records. Attendees are listed in enclosure (1).

2. This was the first meeting of the Data Bus Specification Working Group. The group was welcomed to ARINC Research by Max Duncan, Vice-President and Manager of the Ships and Ordnance Division. The meeting was co-chaired by Tom Sleight, APL and Dan Green, NSWC, Dahlgren. Tom Sleight presented the agenda, enclosure (2), and explained the purpose of the meeting. The agenda was designed to present an overview of the DDGX and the participating laboratories, followed by specification viewpoints from NSWC and JHU/APL. The second day was planned for a discussion of NOSC efforts and splinter group meetings.

3. Tom Sleight handed out a copy of the preliminary Combat System Data Bus Interface Specification Plan to be presented for Capt. Holloway's approval, enclosure (3). He noted the purpose of the plan was to develop GFI for data bus application, not to develop a GFE data bus. The use of the data bus is planned for computers and peripherals, as opposed to ship's data. The DDGX program wants to pay industry to participate in the specification development process.

4. Bob Hill made the presentation of the DDGX overview, enclosure (4), describing a 50 ship program over 12 years with contracting of the lead ship in 1985. He emphasized a balance is being sought between the practical needs for the first ship and the long term needs for the class. A handout, enclosure (5), contains examples of alternate combat system configurations considered for DDGX. Both point-to-point wiring and data bus applications were illustrated. He emphasized that NSWC is the technical support agency (TSA) and will be a focal point for combat system engineering.

5. The next set of presentations was made by the participating laboratories to acquaint the working group with each organization and any data bus experience they may have. Dan Green gave the NSWC presentation, enclosure (6), and noted that the data bus is a tool of combat system designers, and not a combat system design. Tom Sleight made the Applied Physics Lab (APL) presentation, enclosure (7), discussing data bus and distributed processing activities currently ongoing at APL. The NOSC presentation was made in two parts; Dale Bowman presented enclosure (8), stressing the need to look at the total data distribution system consisting of hardwired, switched, and bussed elements, and Bob Reed presented enclosure (9), describing the Ships Data Multiplex System (SDMS) and the low-level serial switch. The NUSC presentation was made by Chuck Arnold of the New London laboratory and Dave Watson of the Newport laboratory, each discussing the organization and experience of their respective organizations. Enclosure (10), a NUSC organization chart, was presented. Chuck Lacijan made the ARINC Research presentation, enclosure (11), showing ARINC Research experience and skills in related areas.

6. At the conclusion of the laboratory presentations, a discussion was held on the Data Bus Interface Specification Plan, enclosure (3). Chuck Lawson stated that the scope of the plan should remain as is, and future efforts, such as looking at other data distribution elements, could possibly be added for FY 82. Some discussion took place on whether the end product of the specification was a bus or an interface to a bus. It was clarified that the specification is for a data bus. Other concerns raised about the plan were:

   - a validation process is required before giving equipment to an integrator
   - the specification should not match an existing industry product
   - the criteria and schedule for industry involvement needs to be established
   - NAVMAT regulations may cause any required bus controller to be a AN/UYK-44

In response to the concerns about industry involvement, Chuck Lawson described how he will use a Basic Ordering Agreement to get industry participation, and noted that a general task statement for the BOA should be developed by the working group.

7. Dan Green presented NSWC's specification viewpoints, enclosure (12). He made the points that the problem is current and of significant magnitude, and gave two examples of what the AEGIS combat system would look like if a data bus was used. The ISO reference model was given as an example of an issue that should be addressed.

8. Al Davidoff presented APL's specification viewpoints, enclosure (13). Issues presented were the level of specificity and whether terminals would be internal or external. Jack Frink followed-up with a presentation, enclosure (14), on the specificity of existing systems, such as MIL-STD-1553 and the Digital Avionics Information System (DAIS). Chuck Arnold stated that the ISO model was adopted to minimize line costs, and local networks, such as a data bus, represent a different problem. He doesn't think we should necessarily adopt the ISO model as a starting point, and offered a model with nine layers of protocol, as contained in enclosure (15). The IEEE effort to establish a standard for interfacing with local area networks, enclosure (16), was also discussed. The meeting was adjourned after a short discussion of the splinter groups needed for the following day's meeting.

9. The second day's meeting was opened with a discussion of the purpose and membership of the splinter groups. The following splinter groups were established:

A. <u>Scope of application (benchmarks)/DDGX data needs</u>

- John Holmes
- Jack Frink
- Bob Reed

B. <u>BOA Statement of Work (industry contracts)</u>

- Chuck Lawson
- Dan Green
- Bob Harper

C. <u>Reference Model (Specificity/ISO)</u>

- Al Davidoff
- Chuck Arnold
- Dale Bowman

D. <u>Internal Working Group Plan</u>

- Tom Sleight
- Al Bernard
- Chuck Lacijan
- Don Doherty
- Dave Watson

10. After separate meetings each splinter group made reports to the full working group. A narrative summary of each report is contained below:

A. Scope of application

The DDGX data transfer should be characterized, identifying such elements as word size, message size, frequency, time criticality, and number of sources and sinks. AEGIS and possibly other ship classes such as carriers and submarines should also be examined to determine current requirements. An explicit effort will be made to determine future requirements. Bus performance capability should then be synthesized. The TSA was identified as a resource to support these tasks.

B. BOA Statement of Work (SOW)

A copy of the SOW developed by this working group is contained in enclosure (17). Comments were provided at the meeting. All subsequent comments should be provided to Chuck Lawson, 06D.

C. Reference Model

This working group reached the following consensus:

- The layered interface/protocol/control ops concept should be maintained.
- The distinction between external terminal and dedicated, embedded terminal should be maintained.
- The distinction between computer and non-computer subscribers should be maintained.
- The word interface should be eliminated from the specification plan, enclosure (3).
- We should track and participate in IEEE and other non-proprietary standard efforts commensurate with schedule.
- Use "waterman" and "otherman" reference models for identifying protocols, interfaces, and control ops needed at each level. This task will be accomplished by a multiple lab effort before the next working group meeting.
- At the next working group meeting, select 1 reference model as the basis for strawman development. This may undergo an iteration from meeting no. 2 to meeting no. 3.
- Subsequent to above, reorganize subcommittees for strawman development.

D. <u>Internal Working Group</u>

The internal working group should become a permanent subcommittee that maintains a "living" plan (POA&M) that is presented at each working group meeting. It should have 3 members plus co-chairmen who meet during each working group meeting. It will start work on an acquisition strategy and end product definition. It recommended that the specification plan acknowledge activity beyond 14 months and that the word interface be deleted.

11. There was general agreement that the specification plan should be modified as recommended. Points of contact were established for each organization as follows:

NOSC - Dale Bowman
NUSC - Chuck Arnold
APL - Tom Sleight
NSWC - Dan Green
ARINC - Dan Kober

Dan Kober will be notified by each subcommittee chairman of all subcommittee meetings and notify Chuck Lawson of same. The next two working group meetings were established for 1-2 October and 6-7 November, both at ARINC starting at 0800. All those presenting vue-graphs at these meetings are requested to bring at least one hard copy of the material presented for the Secretariat.

Drafted by: ______________________
C. A. Lacijan
Secretariat

Approved by: T P Sleight ______________________ E. T. Green ______________________
T. Sleight — Co-Chairman
D. Green — Co-Chairman

Distribution:

See next page

DISTRIBUTION:

C. Arnold, NUSC/NLL
D. Bowman, NOSC
D. Green, NSWC
D. Kober, ARINC Research
T. Sleight, Applied Physics Lab
Capt. L. J. Holloway, NAVSEA 06D
C. E. Lawson, NAVSEA 06DC
A. Bernard, PMS-408
R. T. Hill, NAVSEA 06D6E
D. Marlow, NSWC
D. Watson, NUSC/Npt
J. Holmes, NSWC, Code N51
A. Davidoff, APL
J. Frink, APL
R. Reed, NOSC
V. Meyer, NSWC, Code G-22
D. Doherty, NOSC Code 824
R. F. Rockwell, ARINC Research
M. C. Duncan, ARINC Research
N. Smith, ARINC Research
R. Harper, ARINC Research

Enclosure 1

	Name	Activity	Phone
1.	C. Lawson	NAVSEA 06DC1	202 692-7296
2.	R. T. Hill	NAVSEA 06D6E	202 692-7347
3.	R. F. Rockwell	ARINC Research Corp.	301 266-4961
4.	M. C. Duncan	ARINC Research Corp.	301 266-4900
5.	D. Kober	ARINC Research Corp.	301 266-4965
6.	D. Watson	NUSC/Newport, R. I.	401-841-3354
7.	A. Bernard	NAVSEA PMS 408	202 692-8204
8.	D. Green	NSWC	703-663-7731
9.	J. Holmes	NSWC-N51	703 663-7431
10.	A. Davidoff	APL	301 593-7100 X 3250
11.	T. Sleight	APL	301 593-7100 X 7377
12.	J. Frink	APL	301 593-7100 X 3249
13.	C. Lacijan	ARINC Research Corp.	301 266-4972
14.	R. Reed	NOSC	714 225-6227
15.	Vic Meyer	NSWC (G-22)	A/V 249-7861, C703-663
16.	D. Bowman	NOSC Code 824	714 225-6284
17.	D. Doherty	NOSC Code 824	714 225-[illegible]58
18.	C. Arnold	NUSC Code 313	203 447-4319
19.	N. Smith	ARINC Research Corp.	301-266-4822
20.	R. Harper	ARINC Research Corp.	301-266-4963

APPENDIX B

PROGRAM PLAN FOR DATA TRANSFER
BETWEEN COMBAT SYSTEM COMPONENTS

This appendix reproduces the *Program Plan for Data Transfer Between Combat System Components*, prepared by the Naval Sea Systems Command, Combat System Engineering Office.

FOREWORD

This plan presents a program for the development of an inter-computer/peripheral data transfer mechanism specification for information transfer between combat system components by means of a shared data path, such as a data bus. This specification will be applied initially to the next generation Guided Missile Destroyer, DDGX.

CHAPTER ONE

INTRODUCTION

1.1 PURPOSE

The purpose of this plan is to structure a program for the development of a specification for a mechanism for information transfer between combat system components (inter-computer/peripheral data-transfer) by means of a shared data path, such as a data bus. Figure 1 depicts a generic data bus concept as an alternative to traditional point-to-point interconnections used with weapons, sensors, computers, and peripherals. This specification will be applied initially to the next-generation Guided Missile Destroyer, DDGX. Concurrent efforts will develop specifications for other classes of ships to support both new-construction and major-upgrade programs.

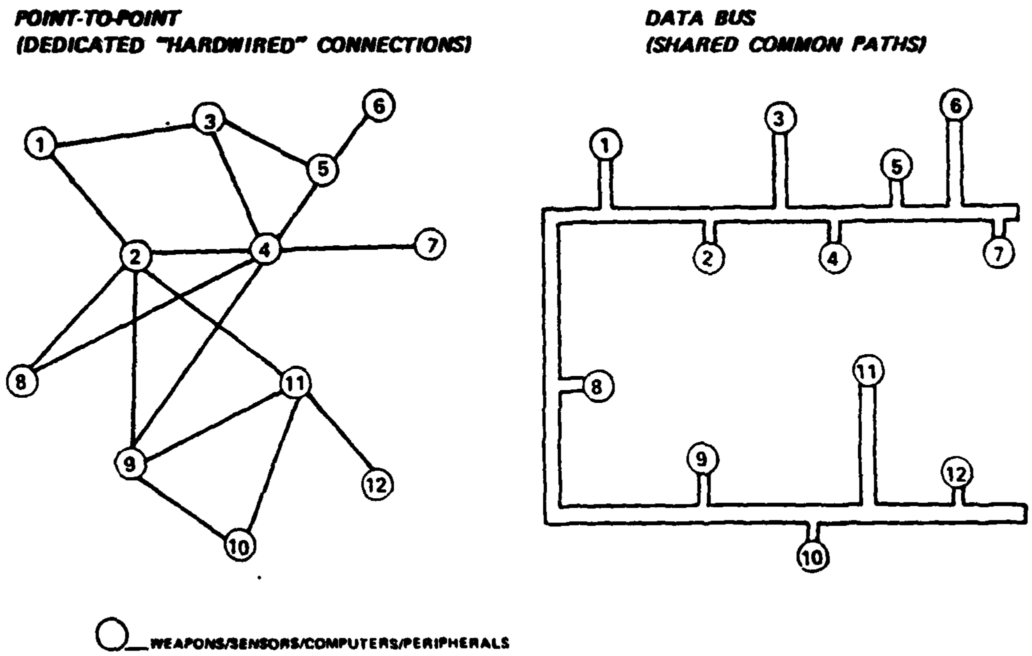

Figure 1. ALTERNATIVE TO POINT-TO-POINT INTERCONNECTIONS

1.2 BACKGROUND

There is great interest in the use of data buses as an alternative to point-to-point interconnections in surface combat systems. In 1978, the

Deputy Assistant Secretary to the Navy (Research, Engineering and Systems) sponsored a Data Bus Panel to investigate the issues. The Air Force has almost ten years' experience employing MIL-STD-1553 as a Government-furnished information (GFI) data bus standard. The Naval Air Systems Command (NAVAIR) currently is adopting the same approach in the F-18, which uses two AN/AYK-14s with MIL-STD-1553 interfaces. In addition, the Navy AN/UYK-43 and AN/UYK-44 computer procurements will provide this bus interface option, as well as other point-to-point interfaces, like STANAG 4153, that are suitable interfaces between components and external terminals. Commercial airline manufacturers began employing data bus standards more than 20 years ago. Industry is actively pursuing independent research and development (IR&D) programs to gain a technical understanding of bus applications and to prepare for future system procurements.

Although the advantages of using a data bus throughout a combat system are yet to be validated, it is clear that some major applications of limited scope will be practical in the near future and have the potential of providing substantial benefits to the Navy.

Distributed data processing with data busing has the potential for solving several problems, two of which are discussed here. First, computations required for the DDGX type combatant are beyond the capability of even the fastest single-processor computer. Thus, it is already necessary to employ simultaneous processing in a great number of interconnected processors. Faster circuits, e.g., very high speed integrated circuits (VHSIC), are being researched but will not be available for application before the 1990s. Even then, the growing complexity of the problem may still require multiple processors. An additional problem is that the adaptation of existing equipment to meet more intense threats is leading to increasingly complex designs. More adaptable and extensible approaches are necessary.

There exists for newer ship classes a reasonably well defined functional hierarchy of systems and equipments:

- Level I - Total ship
- Level II - Ship functions (e.g., combat system, mobility)
- Level III - Subsystem or component (e.g., a total warfare area weapon system)
- Level IV - Elements (e.g., a radar, launcher, or sonar)

For lower-tier (Level IV) elements in the hierarchy, engineers have already chosen distributed processing and busing as effective solutions to requirements. For example, subsystems of the vertical launch system (VLS) and the AEGIS weapon system currently employ data buses. Problems at the higher tiers are related to (1) lack of a recognized central authority to provide the consistent technical direction to implement distributed processing and data busing across many subsystems, and (2) to the real-life constraints imposed by the use of existing designs and computer programs. Therefore, the validity of conclusions is heavily dependent on the level investigated in this hierarchy.

DDGX represents a current opportunity to move toward distributed processing and new data-transmission architectures. The DDGX combat system is being

designed to provide maximum flexibility for system and element-level hardware and computer program upgrades during its life. The combat system is to be designed to be highly survivable and to have a maximum number of alternative or casualty modes of operation. To support these concepts, the Navy must consider the concepts of distributed processing and a compatible data transfer system, as well as traditional point-to-point connected architectures, in the design of the DDGX combat system. The Combat System Engineering Agent (CSEA) for the DDGX program needs to define and develop the requirements for an advanced extensible, flexible, and survivable data-processing/data-transfer architecture suitable for use throughout the entire combat system. He must review applicable Navy data-handling (data-processing/data-transfer) developments and make appropriate recommendations (1) to ensure proper operation of the entire ship and combat system data-handling architectures (wherein many "ship services" functions affect the combat system) and (2) to ensure system flexibility and survivability. The defined architecture is to be compatible with AN/UYK-43/44 and/or AN/UYK-7/20 standard Navy computers and, where feasible, use standard Navy languages, executive programs, and protocols. This effort provides for both near-term inclusion in the combat system of currently planned elements (near-term inventory items that are candidates for first ship use) and for long-term developments of combat system elements. The degree to which such a system will use developmental and/or commercial equipment in the processing phases of land-based test and evaluation will be addressed in future planning.

Future opportunities will be in the Ship System Engineering Standards (SSES) program. The objective of the SSES program is to achieve physical and functional separation of the platform, hull, and its payload elements (Level IV). Engineering standards will be developed to allow the design and construction of the platform independent of, but in concert with, the combat system elements. These standards will be the basis for the development of new classes of ships that are designed and constructed to accommodate easily and quickly, through modular interchangeability, any of the payloads most appropriate to those generic platforms. These standards will also be implemented, as appropriate, in the conversion and modernization of existing ships.

1.3 SCOPE

The specification effort addressed in this plan will define the mechanisms necessary for the components (computer program modules in computers and peripherals) that are a part of weapon, sensor, and control subsystems to communicate effectively among themselves. To this end, a series of interfaces, protocols, and control operations will be specified. This effort will address both the situations in which the physical structure of equipment components (e.g., AN/UYK-7) cannot be cost-effectively modified and the situations, such as in new designs, in which they can be.

Figure 2 provides a simplified representation of one approach to the interfaces. Where a data transfer terminal must be added externally, as to existing equipment using a current MIL-STD-1397 or the new STANAG 4153 interface, the user interface, the external terminal interface, and the connector/cable interface will be specified in sufficient detail so that there can be no ambiguity among various subscribers, data transfer terminal vendors, and

connector/cable vendors. Where the data transfer terminal is added internally, the user interface and the connector/cable interface will be specified in sufficient detail so that there can be no ambiguity between various subscribers and connector/cable vendors. The precise control operations and interfaces will be described functionally, specifying minimum performance requirements, associated protocols, and applicable constraints such as power, weight, cabling, size, and memory requirements.

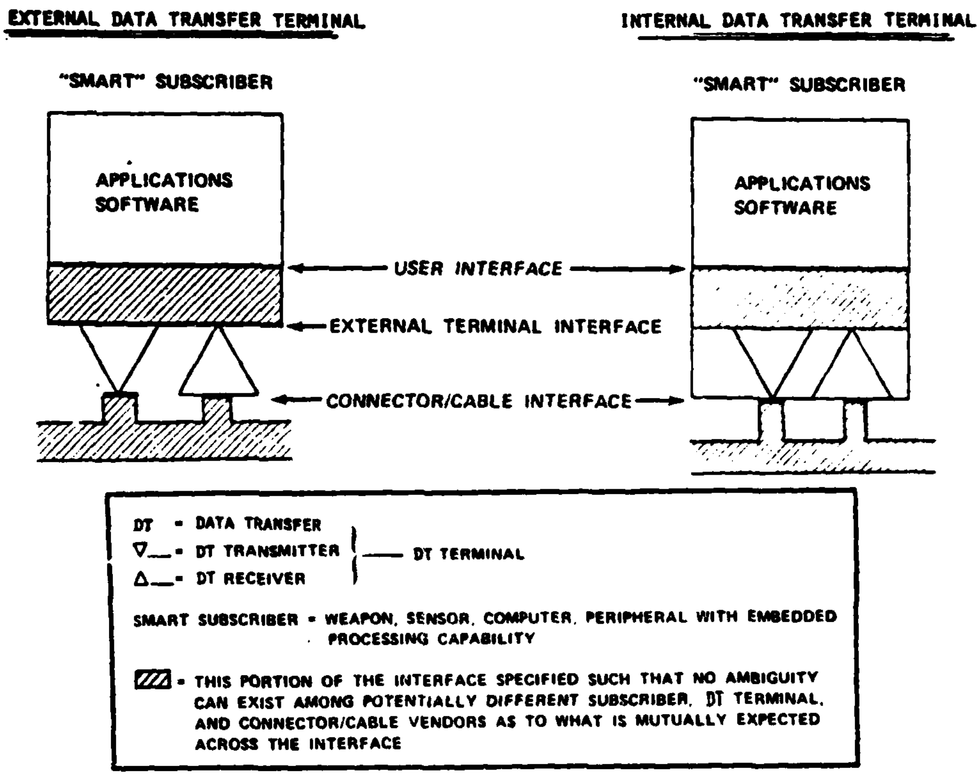

Figure 2. EXAMPLE OF INTERFACE RELATIONSHIPS

With well defined interfaces and protocols, and functionally defined "black boxes" between interfaces, this specification will permit effective competitive procurement of system elements with a common-path interconnection, if desired by the developer. Such freedom of implementation should permit the future evolution of effective common paths throughout a combat system. Figure 3 depicts the potential variability in data transfer implementation in accordance with the approach outlined in Figure 2, showing different subscribers, different data transfer terminals, and connectors and cables supplied by different vendors.

The technical and management insight gained by NAVAIR and the Air Force in the use of the Government-furnished information (GFI) MIL-STD-1553 avionics bus will be an important factor in the development of this specification.

Common user interfaces, future subsystem introduction, and technology insertion will be high-priority factors considered in the protocol deliberations.

In carrying out the detailed deliberations, it will be necessary to consider cabling technology (copper and fiber optics); industry IR&D projects; standardization efforts by the North Atlantic Treaty Organization (NATO), techhnical societies, the National Bureau of Standards, and industry; compatibility with a variety of combat system architectures; effect of application and executive computer programs; and all hardware and software aspects, of input/output (I/O) structure and ship signal data transfer interfaces.

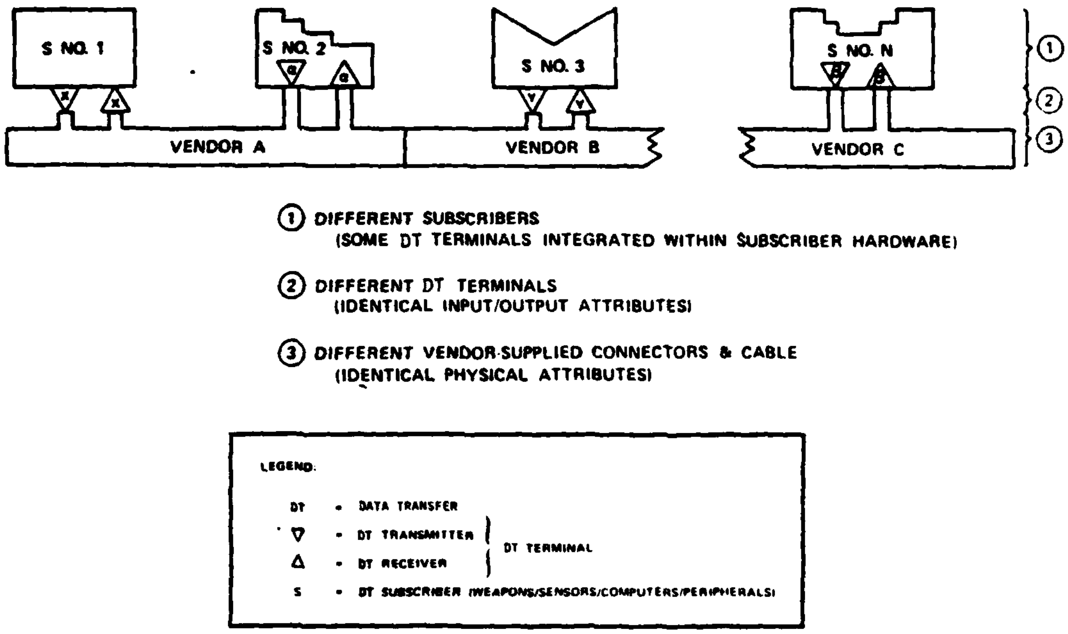

Figure 3. EXAMPLE OF DATA TRANSFER IMPLEMENTATION VARIETY

Except as indicated above, this effort will not directly specify such far-reaching areas as combat system architectures, computer architectures, computer programming languages, Navy standard computer and peripheral acquisitions, and ship signal data transfer systems.

CHAPTER TWO

MANAGEMENT

2.1 OVERVIEW

The management organization for the development of the data transfer specification is designed to provide interaction between combat system users, engineers, Navy system acquisition managers and the DDGX CSEA. A Data Transfer specification working group (DTSWG) and an advisory panel will be formed.

2.2 DATA TRANSFER SPECIFICATION WORKING GROUP

The primary objective of the DTSWG is to produce the data transfer specification. The group will consist of technical personnel from Naval Sea Systems Command (NAVSEA), Naval Surface Weapons Center (NSWC), Naval Ocean Systems Center (NOSC), Naval Underwater System Center (NUSC), Johns Hopkins University/Applied Physics Laboratory (JHU/APL), ARINC Research Corporation, and the DDGX CSEA.

Industrial activities, Navy acquisition managers concerned with data transfer development, and combat system engineers will be solicited for user requirements and technical comments. NAVSEA 06DC will chair the working group; ARINC Research will provide the secretariat for the working group and will, at the direction of the chairman, maintain minutes of the meetings, develop and distribute meeting agendas, and review and consolidate industry comments concerning the specification as it is being developed.

2.3 ADVISORY PANEL

The purpose of the advisory panel is to conduct in-progress reviews of the DTSWG efforts and to provide guidance as necessary. The panel will be chaired by SEA-06D and will initially include representation from SEA-313, -61, -62, -63, -06DC, -06D6, PMS-400, and PMS-408.

CHAPTER THREE

APPROACH

3.1 OVERVIEW

The approach to developing the data transfer specifications will be to establish alternate technical approaches (known as strawmen) and -- through an iterative review process with assistance from industry, potential data transfer producers, and Navy system engineers and acquisition managers --reach agreement on a final specification. In order to bound the approach, reviews will focus on combat system elements planned for DDGX and SSES ships. This plan addresses only the development of the data transfer specifications for DDGX and SSES ships. Subsequent plans will address validation and later phases of this project.

3.2 SCHEDULE

The approach described herein is expected to take 16 months after initiation and is predicated on involvement by industry and Navy acquisition managers. Figure 4 illustrates the program schedule. Subsequent paragraphs discuss each event shown in Figure 4.

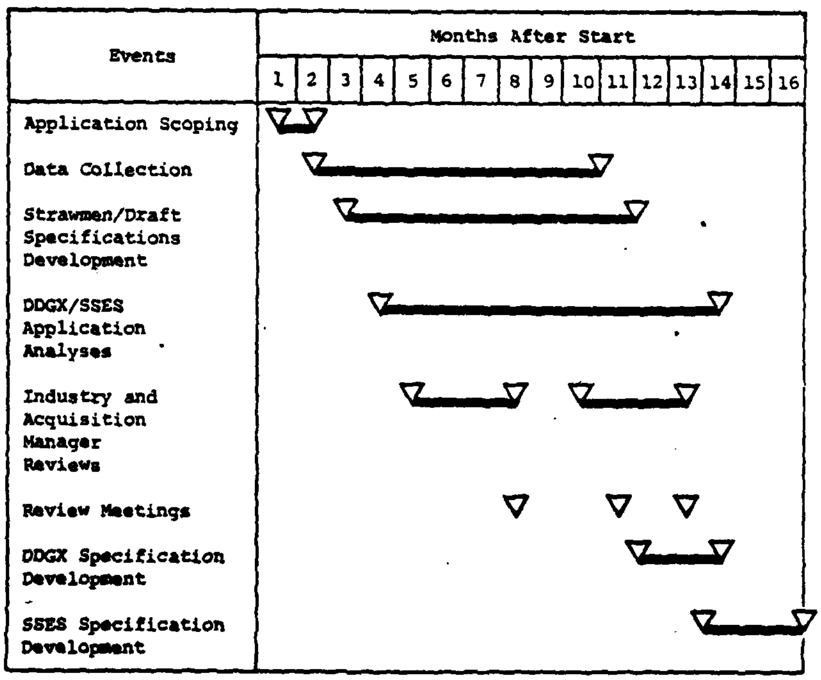

Figure 4. DATA TRANSFER SPECIFICATION WORKING GROUP SCHEDULE

3.3 APPLICATION SCOPING

The initial task for the DTSWG will be to focus on projected Navy combat system requirements and develop an initial set of requirements for the data transfer specifications. Together with the application studies, these will be used later to refine the requirements.

3.4 DATA COLLECTION

In order to assure a good engineering foundation, data will be collected on data-exchange requirements, such as data rates, acceptable delays, message size, message traffic, and acceptable error rates. This effort will be restricted to the elements expected in the combat systems. The exact parameters of combat system elements will not be known for some time, but existing implementations of elements of other combat systems can be examined. Where completely new elements are expected, the DTSWG must rely on engineering judgment. In order to obtain the necessary data, the assistance of various Navy participating managers (PARM) and element contractors will be requested.

3.5 STRAWMEN/DRAFT SPECIFICATIONS DEVELOPMENT

At least three data transfer strawmen will be developed for DDGX, of which one will be the Standard Information Transfer Architecture for Combat Systems (SITACS) developed by NAVSEA-61. The strawmen will be modified as necessary to represent additional or different requirements for other class ships as part of SSES. The strawmen will represent alternate technical approaches for use with DDGX and SSES as appropriate. They will be forwarded to Navy system acquisition managers and to industry for review. As the design progresses and comments are received, a draft specification will be developed from each strawman to further define each technical approach. These draft specifications will be forwarded for comment to the members of the Navy and industrial team who reviewed the strawmen.

3.6 DDGX/SSES APPLICATION ANALYSES

The strawmen, draft specifications, and, ultimately, the final specification will be examined for suitability of application to the DDGX combat system. Items such as ship schedule, development time, cost, combat system design alternatives incorporating data transfer systems, producibility, and advantages or disadvantages to DDGX of the various strawmen, draft specifications, and final specification will be analyzed. This work will be performed by the DDGX Combat System Engineering Office, Technical Support Agent, Combat System Engineering Agent, consultants, and industry representatives familiar with combat system elements and data transfer implementations; guidance and direction will be provided by the DTSWG. Any additional factors pertinent to SSES will be analyzed by the DTSWG, consultants, and industry representatives familiar with combat system elements and data transfer implementations in coordination with SEA-06DC.

3.7 INDUSTRY AND ACQUISITION MANAGER REVIEWS

Timely reviews will be solicited from both the data transfer user community (i.e., applicable system and subsystem acquisition managers and their industry contractors) and the data transfer producing community (i.e., appropriate industry data transfer developers). Following receipt of formal written reviews of the strawmen versions and draft specifications, the DTSWG will invite the reviewers to report orally. All reviewers are expected to quantify alternatives and be prepared to discuss their selections. Open technical discussions will be encouraged.

3.8 REVIEW MEETINGS

The first meeting will be held following DDGX, industry and acquisition management review of the strawmen. Following consideration of the comments, the DTSWG will propose a single draft specification, which will be distributed for review; another user-producer meeting will then be convened.

The DTSWG will establish agenda items that address various aspects of the proposed strawmen or specifications. The secretariat will provide the agenda to the potential meeting attendees when the meeting is announced. During the review meetings, attendees will discuss their concerns and subcommittees will be established to rewrite portions of the strawmen or draft specifications so that controversies or conflicts can be resolved during succeeding days of the meeting. An advisory panel will meet to review progress of the DTSWG as requested by the chairman, SEA-06D.

3.9 DDGX SPECIFICATION DEVELOPMENT

A specification for a mechanism for transfer of DDGX intercomputer/peripheral data will be prepared, incorporating the consensus developed during the reviews of the strawman specifications. This DDGX specification will be forwarded to the DDGX CSEA for implementation.

3.10 SSES SPECIFICATION DEVELOPMENT

Changes necessary to accommodate combat systems of other classes of ships will be made to the DDGX specification to support its use in the SSES program. These changes will satisfy information-transfer requirements of differing combat system architectures not met by the DDGX specification. The specification will then be forwarded to NAVSEA-313.

APPENDIX C

CONFERENCE MINUTES FOR THE SHIP SYSTEM INTEGRATION, INCLUDING COMMAND AND CONTROL CONFERENCE

This appendix presents the minutes of a tri-nation conference (United States, Canada, and Germany) to discuss distributed processing and data busing for ship systems.

CONFERENCE MINUTES FOR THE

SHIP SYSTEM INTEGRATION INCLUDING COMMAND AND CONTROL CONFERENCE

(NATIONAL CENTER #2 ON 3 & 4 March 1981)

Attachment(s) (1) Conference Agenda
(2) Attendees - 3 March 1981
(3) Attendees - 4 March 1981

TUESDAY, March 3, 1981

Capt. R. Rodgers opened the conference with a welcome to the German, Canadian and U.S. attendees. He noted that the intent of the U.S. Navy briefings was to provide information concerning the U.S. Navy commitment to distributed processing/data bussing. He requested questions on an individual briefing be asked during the briefing and introduced a change to the agenda provided as attachment (1). Mr. R. Hill would present an overview of the DDGX design as the first briefing.

DDGX Design Considerations

Mr. R. Hill introduced the DDGX program as design and construction of fifty multi-mission combatants to operate in Battle Groups which would also contain AEGIS ships. He discussed the background leading to DDGX and the studies on methods of data transfer which were conducted as part of the Combat System Architecture (CSA) program. The current DDGX design philosophy stressed:

- quality of organizational management
- quality of information management
- flexibility of design
- flexibility of use

In his position as DDGX Chief Combat Systems Engineer, he is calling for sufficient statistics to support the command delegation process in DDGX. Two points stressed in evolving the design of the combat system for DDGX were

- principle of accessibility of data in making command decisions

- involving personnel in NAVSEA responsible for warfare areas, in invoking design principles

Mr. Hill suggested that in considering the battle organization, we need to answer the question of "What do the humans do?" He presented a functional flow diagram for the combat system, delineating both managerial and executive overtones and indicated that Government contracted efforts will be utilized to bring together system development towards supporting each warfare area including the networking of various supportive elements.

Mr. Hill in addressing information transfer/data bussing, introduced Mr. C. Lawson as the coordinator of "CSA turned DDGX" efforts, in prescribing a candidate medium for information tranfer in the DDGX. Mr. Hill noted that data bussing will not save space and weight over Low Level Serial (LLS), but should offer more flexibility especially in such areas as reconfiguration. The lead ship may use LLS but the class in general should use a bussing concept.

When questioned as to what a CSEA and TSA for DDGX were, Mr. Hill provided the following: The CSEA or Combat System Engineering Agent is a major industrial contractor to be brought in to the program in July 1981. The contractor will be responsible for the systems engineering effort necessary to design the combat system for DDGX. The contractor will be administered and generally monitored by a TSA or Technical Support Agent. The TSA under NSWC; Dahlgren lead will consist of Government laboratories and closely held consultants.

Distributed Processing

Dr. T. Sleight and Mr. D. Green jointly reviewed the subject of Distributed Processing. Dr. Sleight led off with an overview on the status of technology. He noted the prior John Hopkins University/Applied Physics Laboratory experience in data bussing including their current use of a fibre optic bus, and the varied definitions of distributed processing they have come across. He proposed that a layered protocol concept is the key to data transfer interoperability. Additionally, data busses should be categorized in groups by their bandwidth characteristics to aid in comparison. The associated cost of implementing a data bus is considered to be expensive initially but lower on an overall basis. CDR. J. Carruthers presented the viewpoint that the cost is affected by the actual degree of implementation and the associated management concept.

Mr. Green reviewed the distributed processing architecture of the AEGIS Guided Missile Ship - CG 47. He discussed the AEGIS ship combat system

from the view point of a computer specialist. Mr. Green emphasized the current issues associated with combat system designs as

- high life cycle cost
- AN/UYK-7 limitations
- complexity of changes where interdependence make small changes large
- improved fail/soft capability desired
- improved survivability desired
- weight reduction desired

He stated our opportunities to include

- AN/UYK-43/44 currently under development
- NATO Low Level Serial
- data bus technologies
- distributed processing technology efforts

His approach is centered on the position that within a class of ships, all computers look identical to the outside world. His design would provide the data bus as a computer center manager from a functional allocations view point.

Dr. Sleight then summarized the briefings with a discussion on combat system evolution. He reviewed the internal information transfer characteristics of the AEGIS combat system. From a practical approach he stated the need to gain real time tactical experience in DDGX, with the data bus to be introduced as an acquisition approach for new elements of the combat system. A question was asked on the use of a data bus for elements not as reliable as computers. It was noted that the data bus could not only interchange computing facilities which are highly reliable, but the input/output (I/O) ports which are not.

U.S. Navy Data Bus Efforts

Mr. M. Wapner reviewed the research and development programs sponsored by NAVSEA 61 in information transfer. He discussed the Shipboard Distributed Multiplex System (SDMS), as a general purpose data bus for low speed signals (synchros, analog data, discrete signals). It is currently in full scale development with test and evaluation planned in a DD 963 class ship in fiscal year 1982. It will have applications in both submarines and surface ships.

The Advanced Data Transfer System was presented as a high speed (greater than 10 mbps) system. It is under synthesis, simulation and analysis. As part of the Foreign Weapons Evaluation program instituted in January 1980, they are establishing information transfer requirements based on programs underway in foreign navys. These programs include Canadian-SHINPADS; French-Navy CPN/DIGIBOS (low speed multiplex), T-CSF Spiral (high speed distributed network); United Kingdom and German technologies.

Mr. Wapner presented the time schedule for U.S. Navy (USN) review of SHINPADS as

- quantification of USN data loads - March 1981
- simulation using USN data - April 1981
- hardware evaluation - November 1981
- software impact evaluation - June 1982
- distributed data base management - TBD
- hybrid bus/network experiments - TBD
- SHINPADS protocal evaluation - TBD

He discussed the differing approaches of combat system design driving information system transfer architecture versus the architecture driving the system design. A middle grounds approach was suggested.

Advanced Sensor Integration Tactical Data Processing (ASI/TDP) Program

Mr. Phil Andrews presented the Advanced Sensor Integration Tactical Data Processing (ASI/TDP) program underway at the Naval Ocean Systems Center (NOSC). Its objective is to establish a platform level technology base in

- information management
- combat system architecture
- shipboard hardware/software building blocks
- system controlability (human factors)

Other programs underway are

- Ship Combat System Simulation (SCSS) - development of a model to interact node - message - data relationships
- Lightweight Modular Display System - intended to replace the AN/UYQ 21 display

Mr. Andrews noted that an architectural description should include a definition of each subsystem by function, including the methods of interconnection. He stated that systems integration must be implicit within combat systems design. Questions were asked on training and standardization. Mr. Andrews suggested that training has to be a continuing effort. The quantity of maintenance personnel may change dependent on the technology invoked, but a trained operator is still a necessity. Capt. Darwin explained that the AN/UYQ-21 is a limited application standard. He suggested that life cycle cost savings from standardization are important but its emphasis needs to be recognized and evaluated along with other factors such as new technology. He presented a brief overview of the Computer Accreditation efforts as a means of achieving standardization.

Low Level Serial Project

Dr. R. Kolb presented the background and status of the Low Level Serial Project.

Mr. C. Lawson in summarizing the earlier briefings noted that data bussing has and currently is being utilized as a method for information transfer in Navy ships. He reviewed the intent and activities of the Data Bus Working Group in support of the DDGX program and indicated the need to go beyond the DDGX and consider the actual battle group. In addressing this, he welcomed the new membership of NAVELEX PME 108 in the working group.

WEDNESDAY, March 4, 1981

SITACS - Standard Information Transfer Architecture for Combat Systems

Mr. R. Fastring presented the concept of a Standard Information Transfer Architecture for Combat Systems (SITACS). He reviewed the before (1972) and now shipboard data transfer situation. SMDS was designed about 1972 with its signal requirements not well quantified. They were however, reasonably bounded and not too sensitive to ship or combat system architecture. The current situation still shows the convential signals addressed by SDMS but there is an increasing number of processor signals (non-SDMS), and more interest in distributed processing. In reviewing SITACS, he suggested it offered a high speed interconnect mechanism for Navy combat system elements, with sufficiently high modularity, low delay, and high bandwidth to be relatively insensitive to variations in combat system architecture. He indicated that data busses did not provide vertical modularity unless a series of data busses were employed and connected by gateways.

SITACS establishes handshaking on a real end to end basis, but the connection is by trial and error between source and sink. Time delays measured by simulation of networks including up to seven nodes were within that allowed by STANAG 4153. SITACS has limitations in both the broadcast mode and can not be dynamically reconfigured. It does offer however, the use of STANAG 4153 Low Level Serial interfaces and compatibility with centralized, near term federated, and ultimate distributed control architectures.

SHINPADS - Shipboard Integrated Processing and Display System

CDR. J. Carruthers reviewed development and current status of the Shipboard Integrated Processing and Display System (SHINPADS). Integration represents a severe problem in ship design because the equipment installed by the Canadian Navy is multi-national. The use of SHINPADS helps to alleviate this problem. Its conceptual design is based on

- a distributed architecture
- use of standardized displays, computers, software, and input/output port
- a bus-structured "ships" central nervous system

It offers a flexible system of fallback, with the user believing he is connected by dedicated wire. Future efforts are to productize the hardware, and test the system at a test site. SHINPADS is planned to be used in the new Canadian Frigate ship.

Efforts are continuing towards design, fabrication and environmental testing of engineering development models of a multi-redundant interdisplay system to provide the command with sufficient information to operate the ship in accordance with the existing threat. Another effort under exploratory development is digital voice multiplexing for integrated shipboard communications (general telephone, intercom, conference and public announcement). Its architecture is a dual star distributed network.

Fibre Optic Communication Network (FOCON)

The German presentation reviewed the development of a Fibre Optic Communication Network (FOCON). The starting point for its development was consideration of voice transmission and it is being expanded from there.

In presenting an overview of their ship design engineering, they noted determination of requirements for types of ship systems including the use of data busses for information transfer. It is based on an exchange of information between systems, and subsystems structured to enhance the capabilities of the system. The results are provided as guidelines to the contractor and German Navy in developing subsystems.

Working Group Session

Subsequent to the conference, Capt. R. Rodgers held a working group session to review the accomplishments and determine the next action. He noted that the conference had provided an information exchange on "real" systems, and ideas in conceptual and hardware aspects of research and development. He suggested that there are many technical problems and issues and the key to solving them is strong management. On the subject of where do we go from here, CDR. Carruthers suggested that we avoid duplication of

the efforts being worked by the Information Exchange Group - 5, Subgroup 6. He suggested that this two day conference was to expand the efforts beyond the Subgroup 6 activity. He considered that Rear ADMS. F. G. Fellowes, Jr. (USN), D. Wellershoff (GN), and N. D. Brodeur (CF) agreed to this meeting to expedite the process.

Capt. J. Darwin noted that there was no driving force leading to a single approach. Mr. Lawson noted that the Assistant Secretary of the Navy had provided for the use of SDMS and others as necessary to support combat system design. In the DDGX program, the Combat System Engineering Agent (CSEA) will review the development plans for the combat system and the working group under Mr. Lawson will provide guidance in the area of information transfer. He suggested that the SITACS and SHINPADS concepts be presented to his working group for consideration in DDGX.

Discussions centered on integrating the efforts of the U.S. Navy, Germany, and Canada including a potential joint test site. Programs like the Advance Combat Direction System (ACDS) were suggested as candidate vehicles. Capt. Darwin indicated that the U.S. has not yet formulated a position on this matter. The German representatives indicated the same for their country. CDR. Carruthers was in favor of a joint test site and general joint cooperation.

In discussing the NATO Frigate Replacement for the 1990's, it was suggested that a joint venture be started and include other nations beyond those at this conference. It was recommended that the DDGX Information Transfer Committee Chairman, Mr. Lawson, be an observer at the forthcoming IEG-5 meeting in San Diego during the week of 6 April.

Administrative Note - Attendees to the 3 and 4 March 1981 conference are delineated in attachment (2) and (3).

CONFERENCE AGENDA

SYSTEM INTEGRATION INCLUDING COMMAND AND CONTROL

(NATIONAL CENTER #2 Room 9E21)

3 March 1981 -	1000 -	Welcome	CAPT. Rodgers, USN (SEA 612)
	1015 -	Low Level Serial Interface Proj.	Dr. R. Kolb
	1045 -	DDGX Design Considerations	Mr. R. Hill
	1115 -	Technology Status	Dr. T. Sleight
	1145 -	CG-47 AEGIS Combat System	Mr. D. Green
	1215 -	Technology Studies	Dr. R. Kolb
	1245 -	1400 Lunch	
	1400 -	Overview of Data Bus Efforts	Mr. M. Wapner
		. Exploratory Development	
		. Foreign Weapons Evaluation	
	1430 -	Advanced Sensor Integration/ Tactical Data Processing	Mr. P. Andrews
		. Distributive Processing	
	1500 -	Canadian Presentations	
4 March 1981 -	0900 -	German Presentations	
	-	Discussions	

Attachment (1)

Attendees - 3 March 1981

NAME	CODE	NUMBER
CAPT. R. D. RODGERS	SEA-612	692-6291
CAPT. B. M. ERVIN	OP-982F	694-4850
CAPT. J. R. DARWIN	NAVMAT 08D5	692-1204
CAPT. L. B. SYKES	OP-098F	697-1234
J. F. UNCLES	OP-098F2	697-1234
D. T. GREEN	NSWC (N20E)	703-663-7731
D. T. MARLOW	NSWC (K31)	703-663-8221
R. D. HARRISON, JR.	NSWC (N51)	703-663-7431
BDIR HANS POLLE	GE-BEB-FEII5	0261-400-7540
FKPT KLAUS JACOBSEN	GE-FMOD NAV STAFF	0228-125651
KKPT ULRICH POSDZIECH	GE-GENERAL NAV OFFICE	04421-71041-7628
CDR. H. W. SCHAUMBURG	CANADIAN EMBASSY (WASH)	483-5505
CDR. K. J. SUMMERS	NDHQ OTTAWA	613-996-8768
CDR. J. F. CARRUTHERS	NDHQ OTTAWA	613-996-5997 AV-136-5997
L. M. BLACKWELL	SEA-613	692-2011
R. A. FASTRING	SEMCOR	714-299-5860
R. C. KOLB	NOSC	714-225-6176
P. ADAMS	NOSC	714-225-7494
P. J. ANDREWS	SEA-61R2	692-9761
M. WAPNER	SEA-61R	692-9760
T. P. SLEIGHT	JHU/APL	301-953-7100
A. E. DAVIDOFF	JHU/APL	301-953-7100
D. R. KOBER	ARINC	301-266-4965
J. M. NELSON	NSWC/G SOL	703-663-8411
KAREN DOHLER	JHU/APL	301-953-7100
W. J. CURRY	NAVELEXSYSCOM	692-7570
C. LAWSON	SEA-06DC	692-7296
W. E. FIZELL	NAVELEX PME-108	692-7106
R. HILL	SEA-06D6E	692-7296
FKPT G. G. V. KUBIS	GE NAVCCSYSCOM	04421-30671- EXT 4410
K. TOM	ARINC	858-4987

Attendees - 4 March 1981

NAME	CODE	NUMBER
CAPT. R. D. RODGERS	SEA-612	692-6291
CAPT. B. M. ERVIN	OP-982F	694-4850
CAPT. J. R. DARWIN	NAVMAT 08D5	692-1204
H. G. KLOEHN	SEA-614	692-2547
J. F. UNCLES	OP-098F2	697-1234
C. LAWSON	SEA-06DC	692-7296
D. MARLOW	NSWC	703-663-8221
R. D. HARRISON, JR.	NSWC-N51	703-663-7431
KAREN DOHLER	JHU/APL	301-953-7100
A. E. DAVIDOFF	JHU/APL	301-953-7100
FKPT G. G. V. KUBIS	GE NAVCCSYSCOM	04421-30671-4410
FKPT KLAUS JACOBSEN	GE FMOD NAV STAFF	0228-125651
KKPT ULRICH POSDZIECH	GE GENERAL NAV OFFICE	04421-71041-7628
CDR. H. W. SCHAUMBURG	CANADIAN EMBASSY (WASH)	202-483-5505
CDR. K. J. SUMMERS	NDHQ OTTAWA	613-996-8768
CDR. J. F. CARRUTHERS	NDHQ OTTAWA	613-996-5997
R. A. FASTRING	SEMCOR	714-299-5860
P. J. ANDREWS	SEA 61R2	692-9761
R. C. KOLB	NOSC	714-225-6176
P. ADAMS	NOSC	714-225-7494
M. WAPNER	NAVSEA 61R	262-692-9760
L. M. BLOOM	NAVSEA 61424	202-692-2157
L. EVERS	NAVSEA 6131	202-692-2489
J. M. NELSON	NSWC/G5D1	703-663-8411
D. R. KOBER	ARINC	202-858-4965
K. TOM	ARINC	202-858-4987
T. SLEIGHT	JHU/APL	301-953-7100
W. J. CURRY	ELEXSYSCOM	692-7570

Attachment (3)

APPENDIX D

MODELMAN COMMUNICATIONS REFERENCE MODEL FOR COMBAT SYSTEM DATA TRANSFER (INTERCOMPUTER AND COMPUTER-PERIPHERAL)

This appendix describes a communications reference model, designated "Modelman," that serves as an organizing construct in describing data-transfer mechanisms for use in U.S. Navy shipboard combat systems.

Section 1

INTRODUCTION

1.1 PURPOSE OF DOCUMENT

This document describes a Communications Reference Model, titled "Modelman", that serves as an organizing construct in describing data transfer mechanisms for use in US Navy shipboard combat systems. While the model was developed to address inter-computer and computer-peripheral communications, it can be applied to intra-computer communications. It also includes guidance in developing a communications framework for a specific data transfer mechanism and appendices which describe functions representative of each layer of the model and possible hardware examples.

1.2 PURPOSE OF MODELMAN

The Modelman Communications Reference model has been developed to address data transfer requirements of US Navy shipboard combat systems -- characterized by a realtime environment which requires many computers to cooperatively participate in communications with other computers and peripheral devices which serve those computers or are interfaced to the combat system's weapons & sensors. Varied tactical and time-critical tasks are being performed concurrently in each computer. The Modelman Reference Model serves to specifically fulfill the following objectives:

(1) Provide understanding by establishing a common set of terms and definitions about US Navy shipboard Combat System data transfer mechanisms;

(2) Facilitate data transfer mechanism evolution by promoting the use of common logical partitioning (layered protocols) to physical partitioning of hardware and software;

(3) Serve as an organizing principle for the generation of the communications framework for alternative data transfer mechanisms for Guided Missile Destroyer DDGX and Ship System Engineering Standards (SSES) applications;

(4) Serve as a basis to compare existing data transfer mechanisms;

(5) Serve as a descriptive mechanism for future data bus specifications thus permitting evolutionary change by maintaining layer integrity.

Thus, rather than being a specification, Modelman serves as a unifying tool in the development of data transfer mechanisms.

1.3 RELATIONSHIP TO OTHER REFERENCE MODELS

The International Standards Organization (ISO) has completed its sixth formal draft of a reference model for telecommunications applications. The Modelman has evolved from the ISO reference model, maintaining many features of that draft standard in spirit, but deviating where necessary to reflect the US Navy real time system environment. The relationship of Modelman to the ISO efforts is further discussed in Appendix C. Modelman also bears resemblance to a draft model emerging from the IEEE Standards Project 802 charged with developing a local area network standard.

1.4 DEFINITIONS

The following definitions are provided and used throughout the document. For commonality, these definitions should also be used in developing the communications framework of a data transfer mechanism.

1.4.1 Data Transfer Mechanism - The means by which data is exchanged in intercomputer and computer-peripheral communication. Each particular data transfer mechanism will consist of its own physical and logical means of data exchange.

1.4.2 Protocol - The convention or set of conventions which provide for the orderly exchange of data between peer layers of a data transfer mechanism.

1.4.3 Interface - The local boundary between contiguous layers of a data transfer mechanism. This boundary is the sole point of interaction between those two layers.

1.4.4 Segmenting - Dividing large data buffers from other (usually higher) layers into data buffers appropriate to the layer performing the segmenting operation.

1.4.5 Blocking - Constructing data buffers, appropriate to the layer performing the blocking operation from smaller data buffers of other (usually lower) layers. Blocking is often the reconstruction of a large data buffer that was sent in a segmented form.

1.4.6 Peripheral Functions - Tasks, performed by the peripheral devices which use the data transfer mechanism. (See Appendix B).

1.4.7 Tactical Application Software - User-level software which performs a tactical function. Tactical application software modules originate and are the final destination for data buffers.

1.4.8 Subscriber Service Software - User-level software which provides data transfer mechanism services to external units or peripheral functions. Subscriber Service Software Modules do not originate data buffers. Rather, this software translates and passes buffers to or from external equipment which is not capable of directly using the data transfer mechanism in question.

1.4.9 Communications Framework - A basic implementation of the Reference Model which serves as the foundation for strawman data transfer mechanisms. The framework includes the critical components of each layer, and defines sublevels, if any, for each layer (See Appendix ?).

1.4.10 Machine

A hardware device which has resident within it all that is needed to perform one side of the protocols defined by one of the Modelman layers. A machine may perform more than one level of control.

1.4.11 Peer Layers

A set of layers at the same level in the model.

1.4.12 Subscriber

The ultimate computer or peripheral user. Subscribers are considered the physical units which originate or act as a final destination for data buffers. (Refer to Appendix F).

1.4.13 Terminal

A unit composed of the hardware and software necessary to implement at least the Bus/Network Control and Physical layers. (Refer to Appendix F).

Section 2

DESCRIPTION OF MODELMAN

The Modelman is built upon the concept of partitioning the communication control into layers. Each layer contains functions, some of which are directly related to the transfer of data, and others which perform needed housekeeping operations. These functions are performed via communication with peer level functions located elsewhere, through protocols at that level. The protocols are negotiated through the services provided by the next lower level.

Modelman is composed of the following five layers: User, Communication Services, Conversation Services, Bus/Network Control, and Physical and are shown in Figure 1.

2.1 USER LAYER

The User Layer consists of user-specific software which requires the services of the lower layers of Modelman. This software includes tactical application software which directly operates on the data being sent or being received. In some inplementations, software may also include subscriber services software which communicates with equipment outside the machine where the particular User Layer is resident. Subscriber services software, when used, will typically communicate with peripheral devices and computers that do not have the capabilities of the data transfer mechanism covered by this model. Many user-level tasks are expected to operate concurrently within the same machine.

2.2 COMMUNICATION SERVICES LAYER

The Communication Services Layer provides the data transfer primitives to the User Layer. This layer performs, or operates in conjunction with operating system communication control functions. It responds to service requests from User Layer tasks. It characterizes the services provided to the User Layer via the data transfer mechanism. The Communication Services Layer manages the end-to-end transfer of data buffers between different user modules. Data buffers may be segmented, blocked, or neither under the control of this level.

FIGURE 1

MODELMAN REFERENCE MODEL
(17 MAR 81)

LAYERS	FUNCTIONS
USER	– CONTAINS USER-SPECIFIC TASKS WHICH REQUIRE THE SERVICES OF THE LOWER LAYERS
COMMUNICATION SERVICES	– SUPPORTS THE COMMUNICATION OF DATA BUFFERS FROM USER TO USER
CONVERSATION SERVICES	– MANAGES CONNECTIONS BETWEEN USERS
BUS / NETWORK CONTROL	– PROVIDES FOR THE ORDERLY TRANSMISSION OF USER DATA ON TO & OFF THE BUS / NETWORK
PHYSICAL	– ENSURES BIT-LEVEL ACCURACY OF THE DATA TRANSMITTED
MEDIUM	– PROVIDES THE ELECTRICAL/PHYSICAL TRANSMISSION MEDIUM

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2.3 CONVERSATION SERVICES LAYER

The Conversation Services Layer manages the transfer of data involved with individual conversations. This layer establishes and maintains "connections" that provide the required quality and type of service. Connections are accomplished through negotiation with peer conversation services resident in different machines (or the same machine if the transfer is intra-computer).

2.4 BUS/NETWORK CONTROL LAYER

The Bus/Network Control Layer performs the control functions governing the use of the data transfer mechanism's physical medium. This layer controls when a sender transmits his data when a receiver may receive data. Distinctions must be made between those functions that control the medium and those that provide access to the medium.

2.5 PHYSICAL LAYER

The Physical Layer establishes the signal characteristics as well as the medium's mechanical characteristics. This layer ensures bit-level accuracy of the data being transferred.

Section 3

APPLICATION GUIDANCE

As described previously, Modelman is to serve as a basis to generate data transfer mechanisms. For Modelman to fulfill that role, a developer must adhere to a few basic principles. Armed with this common set of reference principles, a developer is to establish a communications framework that embodies his particular data transfer mechanism. This section provides guidance in employing Modelman for such purposes.

3.1 MANDATED FEATURES

The concept and generic description of the five layers of the Modelman Communications Reference Model is essential for comparison purposes and must be maintained in the order given. To aid the developer, Appendix B is provided, which covers representative functions found at each of the Modelman Layers for a bus implementation. For purposes of illustration, a variety of implementation examples are given in Appendix F.

3.2 SUBLAYERING PRIVILEGES

Where suitable classes of functions are clustered together, a developer may elect to define sublayers unique to his data transfer mechanism, provided that he fully defines the functions and interfaces and protocols of each sublayer. An example of sublayering is found in the Communications Services Layer example given in Appendix E.

3.3 TERMINOLOGY

Where a definition has been provided in the main body of this document, the developer will employ that term rather than construct a new one.

3.4 STRAWMAN COMMUNICATIONS FRAMEWORK

Those charged with developing a strawman data transfer mechanism approach will develop a communications framework of their strawman using the terminology and organizing principles found in Modelman. The interfaces between each layer, the protocols of each layer, and the functions embodied within each layer will be described. The communications framework will also describe the hardware implementation schemes realizable with the strawman data transfer mechanism. Appendix F provides illustrations of a variety of hardware/software mappings into the 5-layered Modelman.

APPENDIX E

MODELMAN REPRESENTATIVE FUNCTIONS BY LAYER

This appendix describes a representative communications framework for a data-transfer network in accordance with the Modelman Reference Model. It expands on the reference model by defining characteristic features and functions for each layer.

MODELMAN REPRESENTATIVE FUNCTIONS BY LAYER

1. GENERAL LAYER CHARACTERISTICS

The following list of general layer features serves to establish the nature of the Modelman layers for a bus implementation. This compilation of functions illustrates the method by which the Modelman Reference Model can be applied to form the foundation of a communications framework.

The layers are discussed from highest (User) to lowest (Physical) in this Appendix. In two of the layers, sublevels have been defined. The Communication Services layer is composed of a Handler sublevel, which performs format translations and ensures transparency of data transfer, and a Conveyor sublevel, which manages the end-to-end transfer of data. The Conversation Services Layer is also composed of two sublevels: a Subscriber Selection sublevel contains functions necessary to effect physical data transfer when there is a point-to-point interface between the subscriber and the terminal; and a Conversation Control sublevel negotiates and maintains conversations and performs necessary "housekeeping".

For clarity, a data block will be defined as the unit transmitted by Bus Network Control; the message block, by Conversation Services; the message by Communication Services; and the buffer, by User. A bus controller will be defined as a unit which performs control and monitoring functions over the bus medium; it may or may not be the unit which is transmitting.

1.1 USER LAYER

Runtime Task Modules

Subscriber Services Modules

1.2 COMMUNICATION SERVICES LAYER

1.2.1 Handler Sub-Level

User Calls

Software to Support Circuit Types

Format Conversions

Quality-of-Service Definition

Miscellaneous User Support Services

1.2.2 Conveyor Service Sub-Level

Segmenting of Data Buffers

Address Assignment

Flow Control

Message Routing (to User)

Quality-of-Service Requests

Message Timeout

Sequencing

Retransmission Request Handling

1.3 CONVERSATION SERVICES LAYER

1.3.1 <u>Subscriber Selection Sub-Level</u>

Handshake Control Logic & Interface Protocols

Multiplex Functions

1.3.2 <u>Conversation Control Sub-Level</u>

Connection Management

- Negotiation
- Maintenance
- Notification of Resource Unavailability
- Notification of Compliance/Non-compliance
- Release

Addressing

Priority

Conversation Level Error Handling

Message Block Sequencing

Message Block Handshake/Validation/Retransmission

1.4 BUS/NETWORK CONTROL LAYER

Bus Control

- Bus Access Method
- Bus Allocation
- Bus Test/Reconfiguration
- Bus Monitoring

Priority

Error Checking

Addressing

- Encoding/Decoding

Data Block Sequencing

Handshake
    Word

    Data Block

Data Block Transmission Timing

1.5 PHYSICAL LAYER

Electrical Characteristics

    Signal Levels

    Clock Rate

    Modulation Scheme

Physical Characteristics

    Medium

    Distances between nodes

    Method of bus interface

    Bus topology

Other

    Number of Users

    Number of Channels

    Throughput

    Bit Level Error Checks

    Timing

    Cable & Connector Characteristics

    Nuclear Survivability

2. DESCRIPTION OF LAYER FUNCTIONS

2.1 FUNCTIONS COMMON TO PROTOCOL LAYERS

This section mentions functions which could conceivably be appropriate in any or all layers.

2.1.1 Sequencing

Each layer, with the exception of the Physical Layer, is required to provide some mechanism to ensure the transfer of data units in the proper order. This mechanism could be in the form of a data unit sequence number maintained by both the sender & receiver of data units, a message type indicator, a "more data" indicator, etc.

2.1.2 Segmenting/Blocking

Each layer should, upon receipt of a data unit from the next higher (lower) layer, segment (block) the unit into its own required data unit size. This is due to the fact that no layer should be required to adhere to protocols in other layers, or perform functions specific to protocols in other layers.

2.1.3 Error Checks/Notification/Recovery

Each layer will be responsible for monitoring the transmitted data for potential errors which are peculiar to that layer. A detected error may require notification of the higher layer(s) for the purpose of initiating high level recovery functions. Or recovery operations might be performed by the layer which detected the error.

2.1.4 Timing/Timeout

Timing functions may be performed by any or all layers of Modelman.

2.2 USER LAYER

2.2.1 Runtime Task Module

This user level module performs a tactical function in real time (also called a tactical application computer task). These modules communicate, in general, with other task modules rather than peripheral units external to the bus system.

2.2.2 Subscriber Services Module

Subscriber Services Modules provide communication control services to external computers and peripherals which do not have a direct connection to the bus. These modules operate under the control of the bus-user computer's operating system. Subscriber Services are analogous to the functions of Subscriber Selection (Conversation layer) in that they often manage point-to-point interfaces and associated protocols.

2.3 COMMUNICATION SERVICES LAYER

2.3.1 Handler

2.3.1.1 User Calls

The Handler sublevel responds to calls from users desiring access to bus services. Among the calls which may be made to Handler are:

- o OPEN connection
- o CLOSE connection
- o LISTEN
- o SEND data
- o RECEIVE data
- o REQUEST
- o RESPOND

2.3.1.2 Software to support Circuit Types

Handler must support the circuit type requested or required by the User layer. That is, this sublevel may need to distinguish between messages which require replies and those for which replies are inappropriate. Illustrative examples follow:

- o Handler must be prepared for request/response communication with a virtual circuit connection.
- o Handler may be required to determine which multicast messages received require response or acknowledgement.

2.3.1.3 Format Conversions

Since it is Handler responsibility to ensure transparency of data transfer, format conversion is effected in this sublevel. Handler must translate user format to the form and syntax which is used on the bus. Included among Handler format conversions are:

- o Translations of data representation - single-or multiple-byte numerical data, character representations (ASCII, EBCDIC, etc.), coded sensor data, graphics control and data.

- o Message transfer types - file, line, word.
- o Internetwork Communication - translation from one network protocol to another, when the terminal/computer is serving as an internetwork gateway

2.3.1.4 Quality-of-Service Definition

A user task will require a particular quality of service depending on task priority, the nature of the source and destination, and system environment status (combat or non-combat situation), among others. Handler will define the necessary quality of service relative to these factors and will instruct the Conveyor to implement or request this service.

2.3.1.5 Miscellaneous User Support Services

Handler should provide various services which prepare the users for data transfer and which establish the rules of the conversation. Included among user support services are:

- o synchronization of communicating processes
- o agreement on a privacy mechanism
- o assessment and distribution of costs

2.3.1.6 <u>Conveyor</u>

2.3.2.1 Segmenting of Data Buffers

The initial segmenting of user data buffers occurs in the Conveyor sublevel. (The Handler sublevel does not segment buffers but performs format translations and affixes Handler protocol fields to the data.) Refer to section 2.1.

The Conveyor sublevel is responsible for communicating Conveyor message size to the peer Communication Services layer, if this size has not been predefined for all bus subscribers. When receiving data, this sublevel must block it into buffers depending on the size of messages being received.

2.3.2.2 Address Assignment

Conveyor assigns names (addresses) to user processes for use by itself and the layers below it. This would entail maintaining a list of permanent names for sources and destinations or assigning new addresses for each connection. Conveyor is also responsible for communicating these addresses, as necessary, to peer Communication Services layers.

2.3.2.3 Flow Control

Functions in this category of the Conveyor sublevel may operate in conjunction with routing and segmenting functions in that the rate of data transfer between users could be a function of the amount of buffer space available to a single user and the size of the messages being transferred. Through Communications Services peer protocol, the receiving Conveyor level may be able to meter the rate at which the sender transmits data.

2.3.2.4 Message Routing (to User)

Routing of data buffers from the bus to the user is performed in Communication Services. These routing functions occupy the Conveyor Sublevel since Conveyor ensures that all buffers formed at higher layers are sent and received via Conversation level connections.

2.3.2.5 Quality-of-Service Requests

The quality of service (response time, error rate, etc.) that is required by a particular user is defined in Handler. Conveyor is responsible for interpreting the defined service requirements and making requests to the Conversation layer to negotiate a connection which will provide the necessary service.

2.3.2.6 Message Timeout

See Section 2.1

2.3.2.7 Sequencing

See Section 2.1

2.3.2.8 Retransmission Request Handling

Communication Services handles end-to-end retransmission requests, through Conveyor peer protocol, prior to data buffers' being passed to the User layer.

2.4 CONVERSATION SERVICES LAYER

2.4.1 Subscriber Selection

2.4.1.1 Handshake Control Logic & Interface Protocols

This sublevel provides for the necessary protocols and handshake frames or signals which are required by the particular point-to-point interface(s), including proper timing and signal levels. For example, Subscriber Selection will handle, among others:

- ODR/ODA, IDR/IDA, etc., for MIL-STD-1397
- SIS, SOS control frames for STANAG 4153

2.4.1.2 Multiplexing

Subscriber Selection-level multiplexing concerns the case in which multiple hosts (computing elements which contain the User and Communication Services layers) must be serviced over a switched point-to-point link. Subscriber Selection must notify Conversation Control as to which host (user) is transferring data.

2.4.2 Conversation Control

2.4.2.1 Connection Management

The purpose of connection management is to establish and maintain data communication (connections) between bus users. Among the functions encompassed by Connection management are connection negotiation, connection maintenance, notification of compliance/non-compliance, notification of resource unavailability, and connection release.

2.4.2.1.1 Connection Negotiation

During the negotiation phase, the Conversation Layer must initialize the parameters pertinent to the new conversation. These include source/destination addresses, service type & class required, circuit type (virtual circuit, datagram, etc.) & message sequence indicator, among others. The Conversation Layer must also notify its peer Conversation Layer of parameters which must be used or included in data units exchanged on the new connection.

2.4.2.1.2 Connection Maintenance

A record must be maintained, in the Conversation Layer, of parameters pertinent to all current conversations. In addition, the layer must be able to accommodate any desired or necessary changes of the parameters on request from a peer Conversation Layer or from its own next higher layer.

2.4.2.1.3 Notification of Compliance/Non-compliance

Conversation Services protocol may require that this layer notify a peer Conversation Layer as to its ability to honor a request for a certain service or connection type. This notification could occur during either connection negotiation or maintenance phase.

2.4.2.1.4 Notification of Resource Unavailability

During the course of a conversation (either negotiation or maintenance phase), a host resource may become unavailable for service to bus users. In this case, the Conversation Layer is responsible for notifying peer Conversation Layers, desiring or holding conversations with the host resource, of its unavailablility.

2.4.2.1.5 Connection Release

The Conversation Layer must provide for the orderly termination of a connection without loss of data when possible, on request from an upper layer or a peer Conversation Layer. Connection release may precede the renegotiation of conversation parameters.

An emergency release or abort would be provided for at this layer. Abort would releas- the connection but not necessarily prevent data loss between users, and notification of the abort may be required.

2.4.2.2 Addressing

Translating logical or functional addresses into physical addresses (bit patterns) is a function of the Conversation Services Layer, as is relating source and destination addresses to a particular connection.

2.4.2.3 Priority

Message priority addressed in this layer concerns message blocks which have been designated by the Conversation Layer as having priority over previous messages transmitted over the same connection.

2.4.2.4 Error Checking And Handling

At the Conversation Services Level error checking includes:

Connection Management Errors

Addressing Errors

Negotiation Procedure Errors

Message Block Format Errors

Message Block Timing, Sequencing Errors

2.4.2.5 Message Block Sequencing

See Section 2.1

2.4.2.6 Message Block Handshake/Validation/Retransmission

This heading encompasses functions that support virtual circuit transmission. Handshake could be accomplished through ACK/NAK, Request/Response. Functions in this category work in conjunction with Conversation Level error checking for message block validation.

2.5 BUS/NETWORK CONTROL LAYER

Since operations performed by the bus controller differ from those performed by other units, the functions in the Bus/Network Control Layer have been designated as pertaining to the controller, the non-controller, or both.

2.5.1 Bus Control

Among the functions encompassed by Bus Control are bus access protocol, bus allocation, bus test and reconfiguration, and bus traffic monitoring. The types of entities performing the functions can be diverse in nature. For example, bus monitoring and test may be performed by a different unit than that which is performing other bus control functions; or the same unit might be responsible for all functions.

Likewise, the controller functions might be distributed among elements on the bus or be handled by an individual control unit. In the latter case, the controller could be a dedicated unit, a bus-service subscriber which is acting as controller (temporary or permanent), or a combination of the two.

Each Bus/Network Control function will be addressed individually.

2.5.1.1 Bus Access (Controller/Non-controller)

Each bus access method, though usually associated with one type of control scheme, can be used in systems with distributed controllers, individual controllers, or combinations of these.

- Contention - distributed controller
  In Carrier Sense Multiple Access with Collision Detection (CSMA/CD) control of bus access and the accompanying back-off schemes are usually distributed among all units

- Contention - individual controller
  A bus monitor could alter collision back-off interval of non-controller units during periods of heavy bus traffic

- Token - individual controller
  Total bus control, in the case of dynamic bus allocation, can be offered (in the form of a token) to another unit by the present bus controller.

- Token - distributed master
  With all units sharing control, right-to-transmit might be passed for only a single transmission

2.5.1.2 Bus Allocation (Controller)

This heading encompasses such functions as permission-to-transmit request/grant, and "turns". Turns could be an explicit function of a dedicated or individual controller, or an implicit function in the case of a distributed controller.

Illustrative examples of bus allocation include:

- permission-to-transmit granted, via control words, to a single unit by the bus controller.

- right to transmit may be granted in the case of a ring-type bus, to the immediately subsequent unit.

- right to transmit may be passed to a single unit whose identity has been previously defined.

- length of the back-off interval (in CSMA/CD) might determine the amount of bus service allocated to a particular unit.

2.5.1.3 Bus Test/Reconfiguration (Controller)

Bus test will include tests of the medium, terminal units & the controller (self-test). In addition, diagnostics for subscriber use & test of the subscriber system may fall into this category. Bus test can be active (eg. polling terminal units for status) or passive (eg. monitoring selected bus transmissions - this could work in conjunction with Bus Traffic Monitoring).

The Reconfiguration function includes switch to backup systems, rerouting around a failed element, and remedial action (eg. terminal reset).

2.5.1.4 Bus Traffic Monitoring (Controller)

This category includes monitoring the volume of traffic on the bus as a whole, or from an individual terminal, to detect bottlenecks and other traffic irregularities. Functions at this level ensure that no terminal monopolizes the bus; this could be accomplished through affecting the back-off scheme in CSMA/CD or disabling the terminal, among others. Rerouting of traffic is also performed around bottlenecks.

Note that functions in this category overlap or work in conjunction with functions considered as Bus Test/Reconfiguration.

2.5.2 Priority (Controller and/or Non-controller)

Two types of priority are addressed by the Bus/Network Control Layer: subscriber priority and message priority.

2.5.2.1 Subscriber Priority

Certain terminals or subscribers may be polled more frequently by the controller than others, or, in the case of contention-type access, may back-off for a shorter interval than other units.

2.5.2.2 Message Priority

Certain messages may be given higher priority than others when being placed on the bus, for example command and control messages. (The Conservation Layer also addresses priority).

2.5.3 Error Checking and Handling (Controller/Non-controller)

Note: Each layer will have error handlers pertinent to its own functions.

At the Bus/Network Control Level error checking includes:

Word Length
Data Block Length
Data Block Format
Word Format
Bus Allocation
Timing
Frame Checks

2.5.4 Addressing (Controller/Non-controller)

The encoding and decoding of address fields in message blocks are effected in the Bus Network Control Layer. This does not include translation of logical addresses to physical addresses (bit, patterns), which will be handled by the Conversation Services Layer.

2.5.5 Data Block Sequencing (Controller/Non-controller)

See Section 2.1

2.5.6 Handshake

Handshake functions either overlap or work in conjunction with Error Checking functions.

2.5.6.1 Word Handshake (Controller/Non-controller)

This category encompasses such functions as parity checks, word format checks, ACK/NAK of invalid words, and interpretation of Ready-to-Send, Ready-to-Receive signals.

2.5.6.2 Data Block Handshake (Controller/Non-controller)

Data block handshake functions include CRC checks, format checks and ACK/NAK of invalid data blocks. In addition, certain sequencing functions would be performed at this level. For example, if the particular message just received must be followed by another message of a specified type, receipt of a message of invalid type could indicate a sequencing error.

2.5.7 Data Block Transmission Timing (Controller/Non-controller)

Functions in the Bus/Network Control Layer measure/generate intermessage time intervals and intramessage intervals (eg. time between the transmission of the "RECEIVE" command (from the controller) and the transmitted data). The bus access timing mechanisms reside in this layer.

2.5.8 Additional Bus/Network Control Functions

The Bus/Network Control Layer must provide the requested quality of Service to the Conversation Layer i.e. normal or expedited data transfer, required error rate, etc. This service must be provided in the most cost-effective manner, and the Bus/Network Control must therefore perform such functions as routing to minimize access delay, and maximize throughput.

2.6 PHYSICAL LAYER

At this level, the nature of most characteristics is self-explanatory. Only a few need be elaborated.

2.6.1 <u>Bit Level Error Check</u>

At the Physical Level, error checking includes:

Parity

Modulation

Synchronization

2.6.2 <u>Timing</u>

The timing functions performed in the Physical Layer consist of control of the bit transmission rate and bit modulation.

APPENDIX F

MODELMAN HARDWARE IMPLEMENTATION EXAMPLES

This appendix presents examples of hardware implementation for a data-transfer network that conforms to the Modelman Reference Model.

MODELMAN HARDWARE IMPLEMENTATION EXAMPLES

The Modelman Reference Model has been consciously defined to permit three different terminal implementations: Embedded Case, External Terminal Case, and Enhanced External Terminal Case. Specific Strawman approaches may address any or all of these cases.

1.1 EMBEDDED CASE

This configuration concerns a bus subscriber which contains all data bus hardware, and the software to control it, within itself (See Figure F-1). All Modelman layers reside in the subscriber computer.

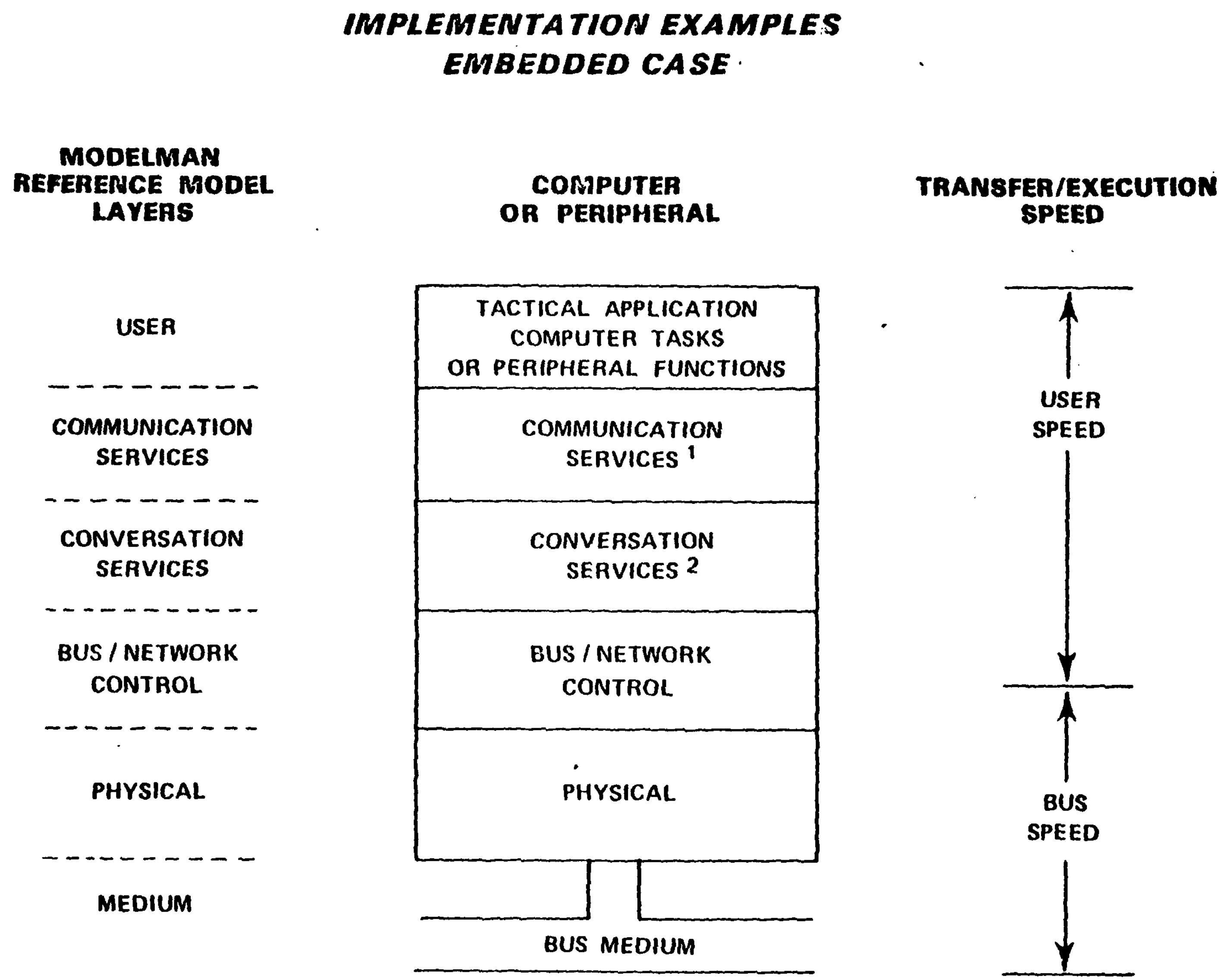
1.2 EXTERNAL TERMINAL CASE

This implementation concerns a case in which the terminal (hardware and software pertinent to data bus operation) is physically separate from the bus subscriber (See Figure F-2). Here, the subscriber's operating system requires modification to permit control of and communication with the External Terminal.

In this configuration, there is a physical point-to-point interface between the subscriber and the terminal. Further, there is a possibility of multiple subscriber computing elements gaining bus access through a single terminal; this could require a switched point-to-point link. The switching control would reside in Conversation Services. External Terminal subscribers will generally be computers; it is anticipated that few present-day peripherals will be capable of performing the higher layer functions necessary in External Terminal Configurations.

If the subscriber computing element connects and provides communication features to an external element (via direct or switched point-to-point), the point-to-point interface control will typically be a function of the computing element's operating system or executive.

FIGURE F-1



[1] SUBLEVELS – HANDLER, CONVEYOR SERVICE

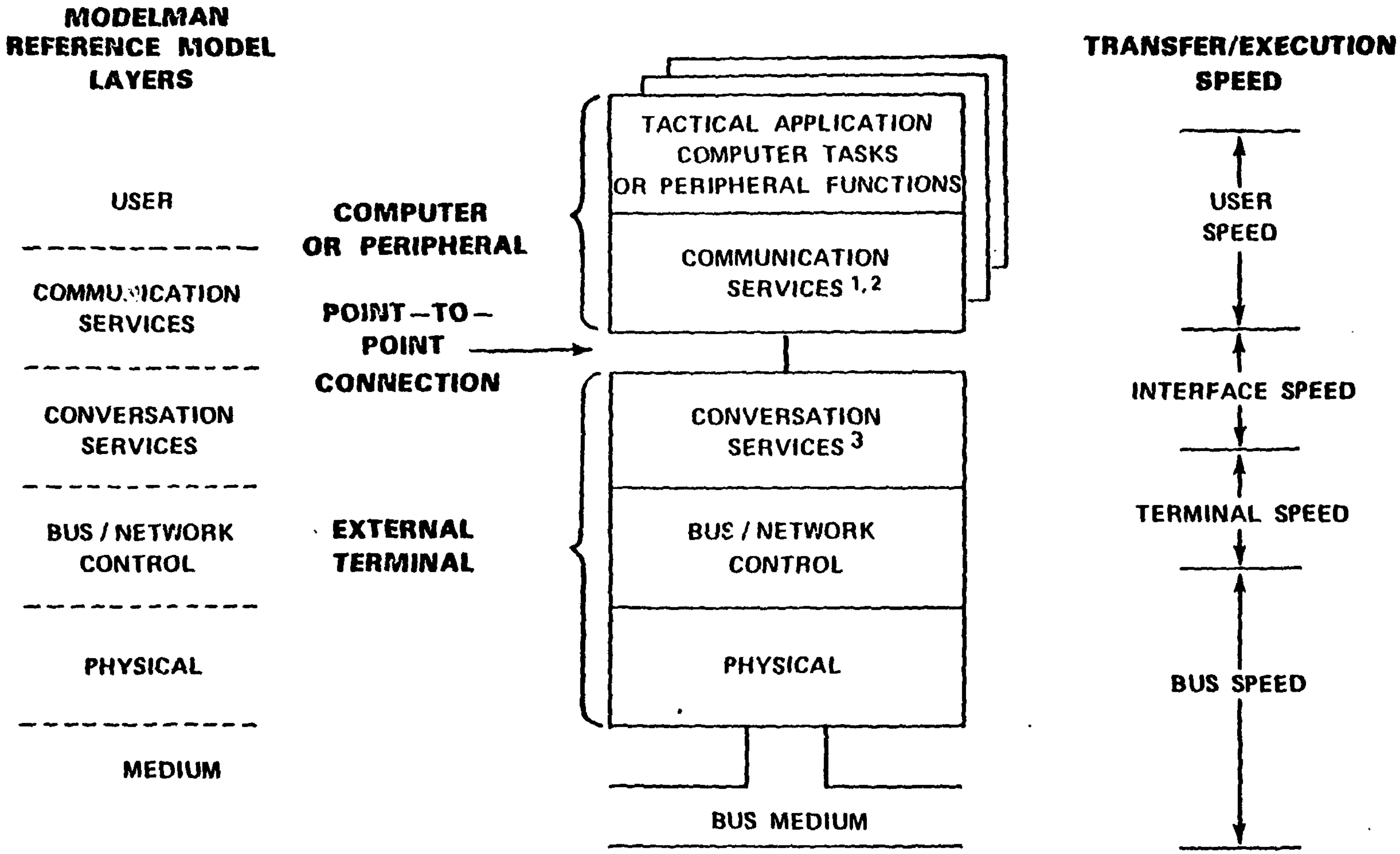
[2] SUBLEVELS – SUBSCRIBER SELECTION, CONVERSATION CONTROL

REFERENCE MODEL – 17 MAR 81

1-3328
APR 81

FIGURE F-2

IMPLEMENTATION EXAMPLES EXTERNAL TERMINAL CASE



1 REQUIRES MODIFICATION OF EXISTING OPERATING SYSTEM

2 SUBLEVELS – HANDLER, CONVEYOR SERVICE

3 SUBLEVELS – SUBSCRIBER SELECTION, CONVERSATION CONTROL
REFERENCE MODEL – 17 MAR 81

1-333B
APR 81

1.3 ENHANCED EXTERNAL TERMINAL CASE

The Enhanced External Terminal (Figure F-3) can be considered a highly intelligent "black box" which is capable of performing all data bus operations. It is tailored to the case where only minimal software modifications, and no hardware modifications can be made to the subscriber. All Modelman layers are implemented in the Enhanced External Terminal.

The terminal can provide bus services to many subscribers, including computers and smart and dumb peripherals, via direct or switched point-to-point interfaces. Control of these interfaces resides in the Enhanced Terminal's User layer (Subscriber Service Modules). Multiple interfaces of various types (NTDS, STANAG 4153, etc) can be accommodated simultaneously by the Enhanced Terminal.

Note that the subscriber computer, in this case, will be executing User-level Runtime Task Modules.

1.4 ADDITIONAL IMPLEMENTATIONS

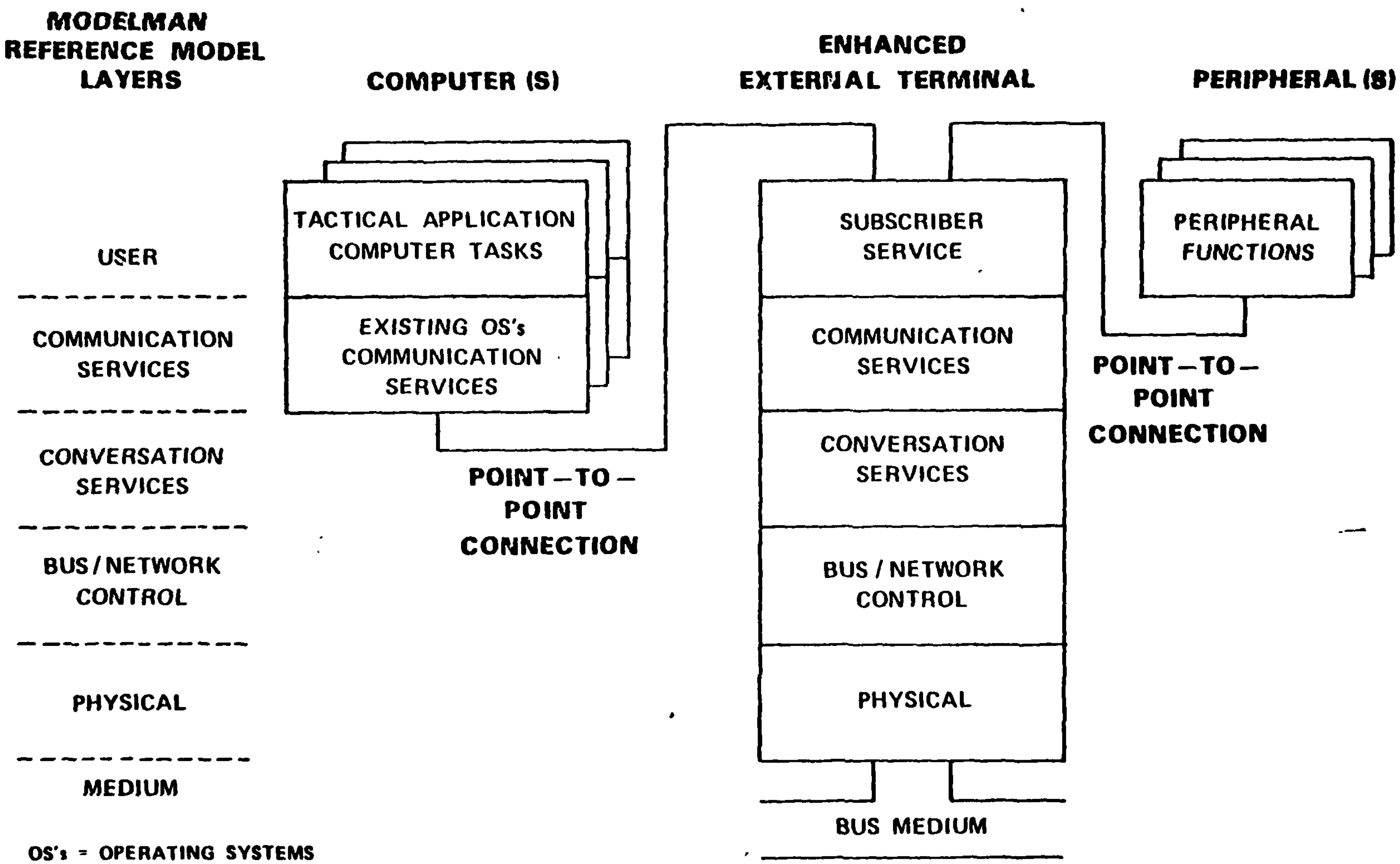
The Modelman Reference Model, while addressing data transfer mechanisms, does not imply that layering principles are inappropriate for direct connections. With some modifications, Modelman can be applied to both direct and switched point-to-point connections and intracomputer communication as well.

In such instances, communication between users requires only selected services of lower protocol layers of this Reference Model. In the case of intracomputer communication (where user processes reside in the same computer), the management of conversations is required by the higher layers, although no physical interface between users exists (Figure F-4). In the case of point-to-point (where a direct connection between computers precludes or eliminates the need for bus medium access), the physical control and data block transfer control functions are required although they pertain to the point-to-point connection rather than to a bus (Figures F-5,F-6).

To accommodate these selected services a two-layer Bus Emulation Service construct has been added. Bus Emulation Service performs functions analogous to those located in the Conversation Services and Bus Network Control Layers. It therefore presents to the upper layers the appearance of connection to a bus network, and it provides services necessary for the maintenance of conversations and

IMPLEMENTATION EXAMPLES
ENHANCED EXTERNAL TERMINAL
MINIMAL USER SOFTWARE/HARDWARE IMPACT

FIGURE F-3



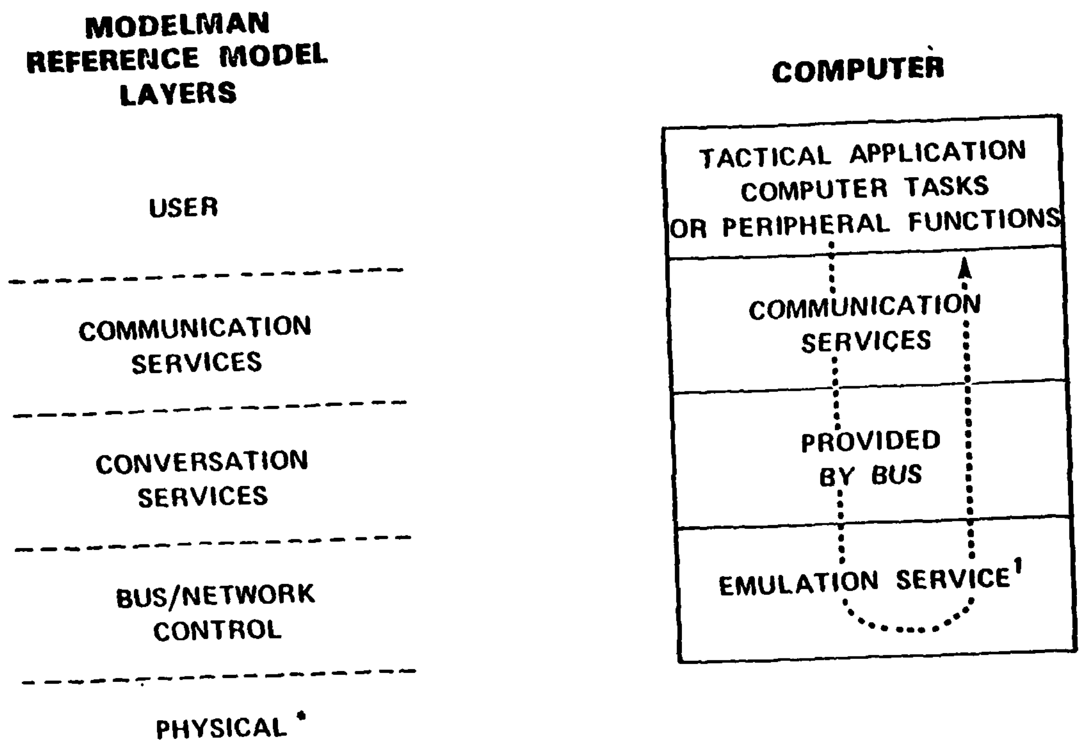
OS's = OPERATING SYSTEMS

REFERENCE MODEL – 17 MAR 81

1-334C
APR 81

IMPLEMENTATION EXAMPLE
INTRA–COMPUTER COMMUNICATION

FIGURE F-4



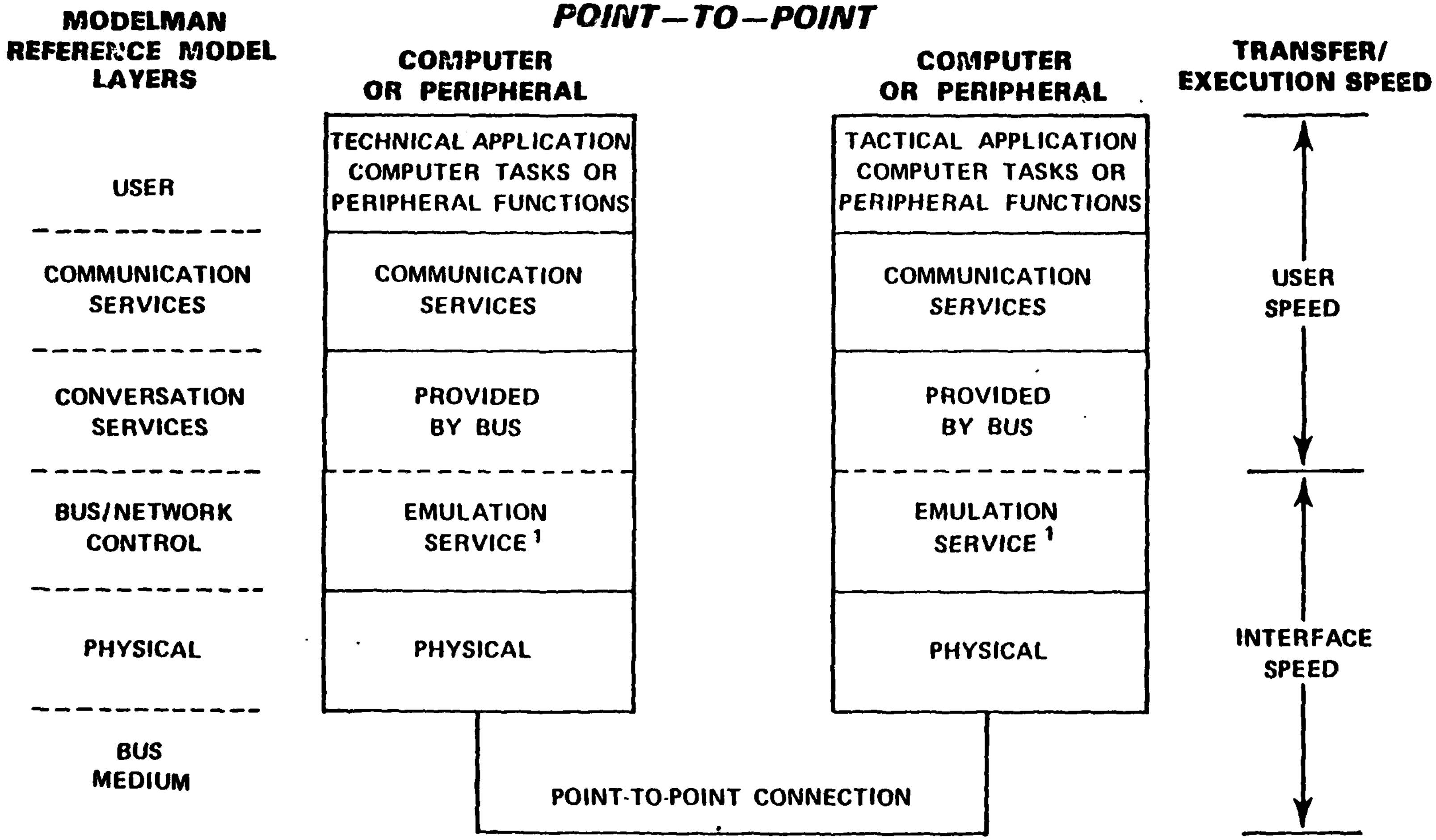
* NOT NEEDED
REFERENCE MODEL – 17 MAR 81

1 CERTAIN FUNCTIONS ANALOGOUS TO THOSE LOCATED IN THE CONVERSATION SERVICES & BUS NETWORK CONTROL LAYERS MUST BE PERFORMED

1-335B
APR 81

FIGURE F-5

IMPLEMENTATION EXAMPLE POINT—TO—POINT



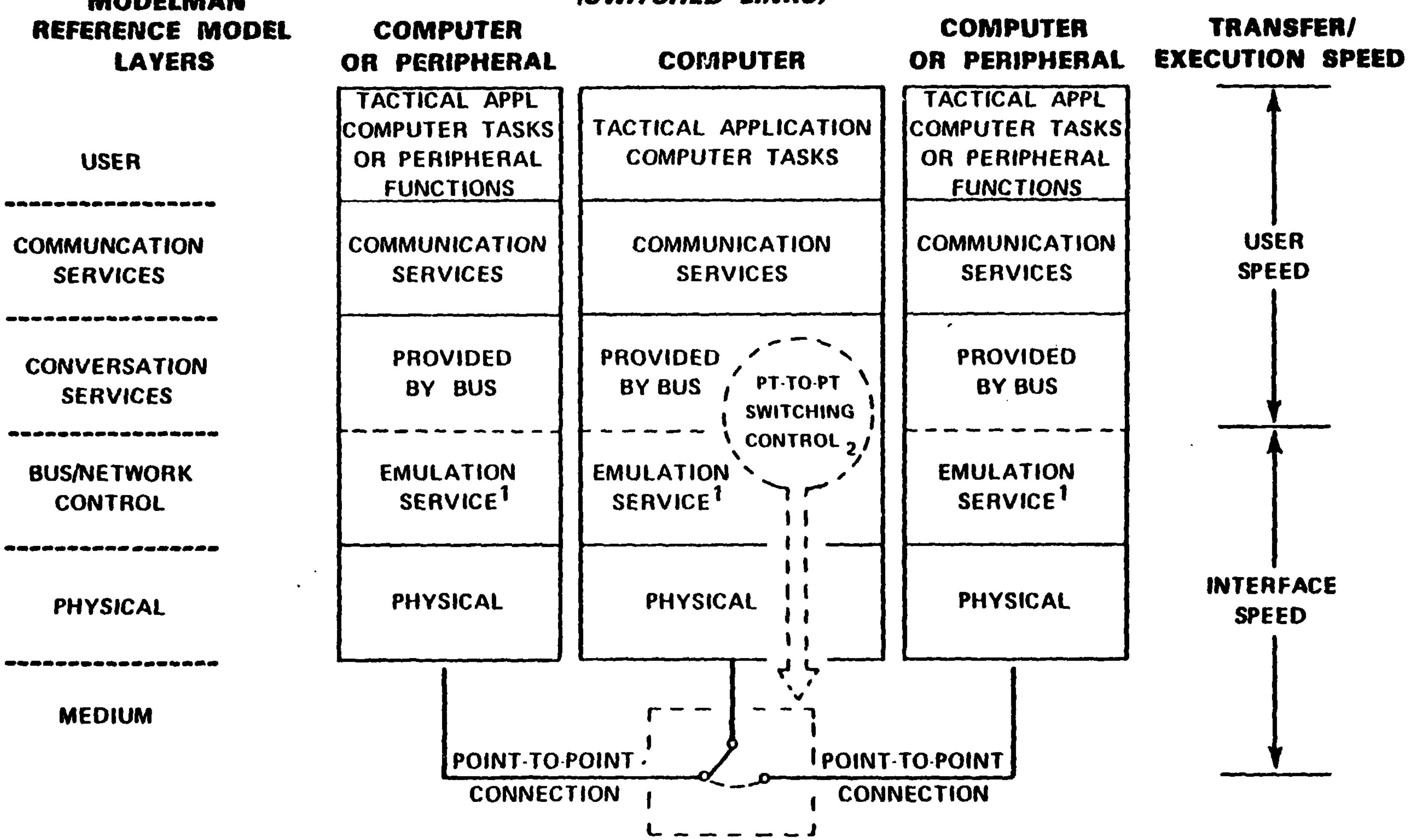
[1] ALTHOUGH THERE IS NO ACTUAL CONNECTION TO A DATA BUS, CERTAIN FUNCTIONS ANALOGOUS TO THOSE LOCATED IN THE CONVERSATION SERVICES & BUS NETWORK CONTROL LAYERS MUST BE PERFORMED

REFERENCE MODEL – 17 MAR 81

1-336B
APR 81

FIGURE F-6

IMPLEMENTATION EXAMPLE
POINT-TO-POINT
(SWITCHED LINKS)



[1] CERTAIN FUNCTIONS ANALOGOUS TO THOSE LOCATED IN THE CONVERSATION SERVICES AND BUS NETWORK CONTROL LAYERS MUST BE PERFORMED

[2] SWITCHING CONTROL IS PERFORMED BY BUS EMULATION SERVICE AND IS TRANSPARENT TO HIGHER LAYERS

REFERENCE MODEL: 17 MAR 81

1-477C
APR 81

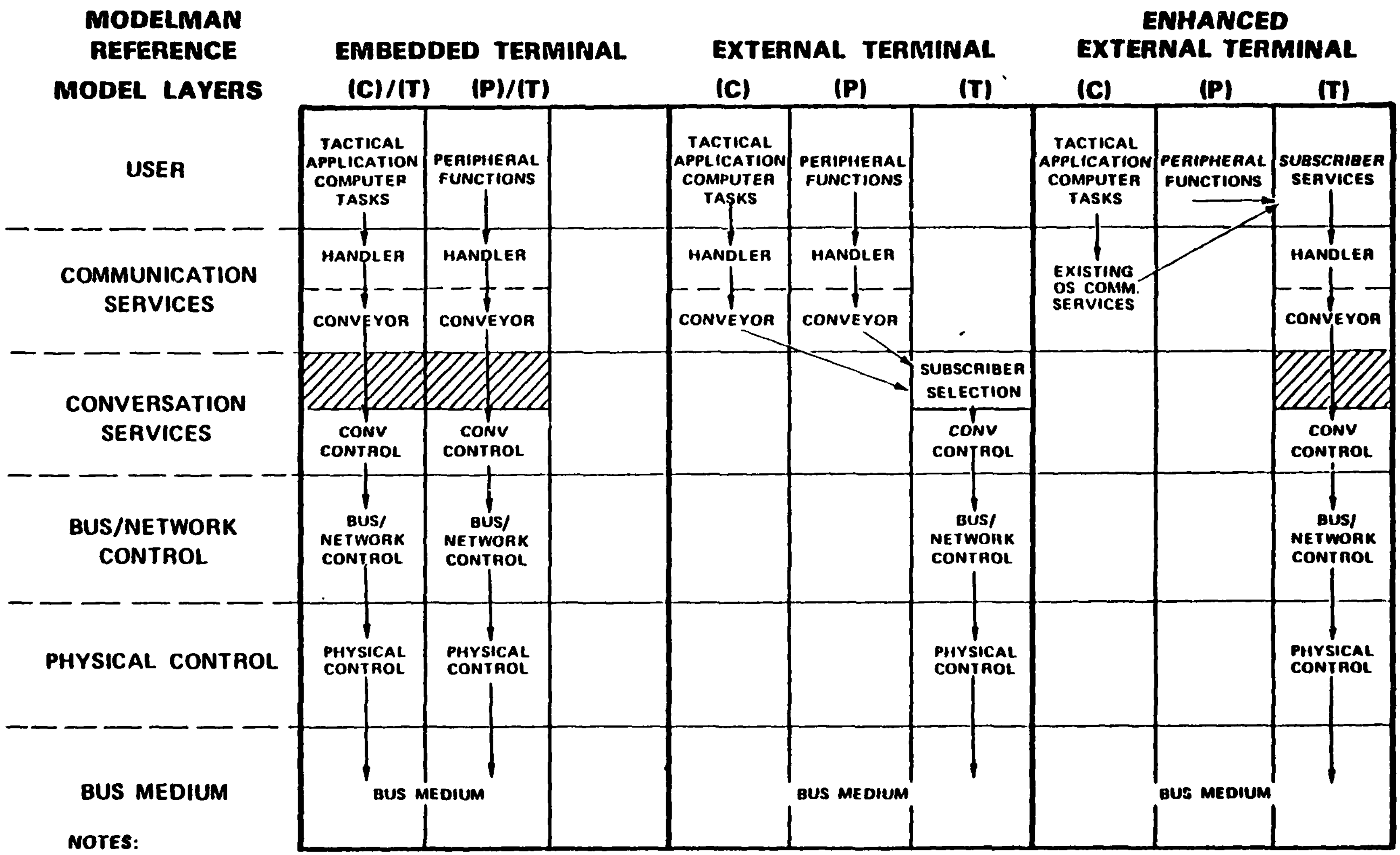
the orderly transfer of data. Ideally, the Communication Services Layer should not be able to distinguish between the services provided by Conversation and those provided by Bus Emulation.

1.5 IMPLEMENTATION SUMMARY

Figures F-7 and F-8 summarize the previously described hardware implementation examples of the Reference Model. These figures indicate the location in hardware of each of the Modelman layers. Also indicated is the flow of data, as well as control over data, through each layer and sublayer defined in Appendix E.

FIGURE F-7

IMPLEMENTATION EXAMPLES



NOTES:

1 ( ) HARDWARE IN WHICH FUNCTIONS RESIDE

(C) = COMPUTER
(P) = PERIPHERAL
(T) = TERMINAL
(M) = PHYSICAL MEDIUM

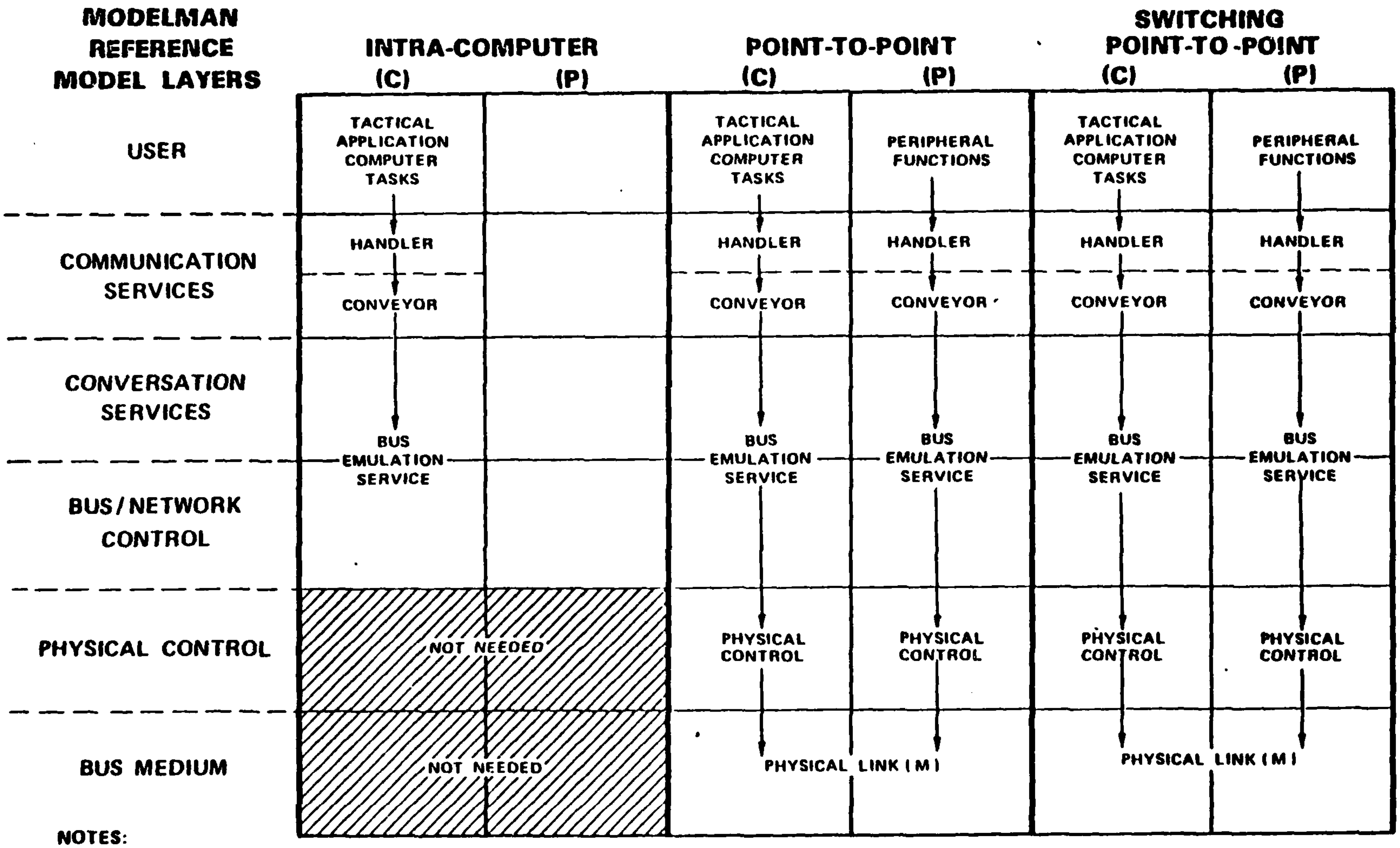
2 [hatched box] INDICATES SUBLEVEL IS NULL IN THIS CASE

3 ARROWS INDICATE TRAVERSAL OF LAYER OR SUBLEVEL INTERFACE

1-563A
APR 81

FIGURE F-8

IMPLEMENTATION EXAMPLES (CONT.)



NOTES:

1 ( ) HARDWARE IN WHICH FUNCTIONS RESIDE

(C) = COMPUTER

(P) = PERIPHERAL

(M) = PHYSICAL MEDIUM

2 ▨ INDICATES LAYER OR SUBLEVEL IS NULL IN THIS CASE

3 ARROWS INDICATE TRAVERSAL OF LAYER OR SUBLEVEL INTERFACE

1-564A
APR 81

APPENDIX G

TECHNICAL COMMENTS ON THE SITACS PLAN

This appendix is a consolidation of the technical comments obtained from a review of the SEA-61 SITACS proposal by members of the DBSWG.

The purpose of the SITACS plan was to stress compatibility with existing designs and independence from combat system architectures as primary goals. However, emphasis is solely on a fixed architecture of Low-Level Serial (LLS) interfaces with LLS switching, thus excluding at the outset all other possible approaches. The objective of being maximally compatible with STANAG 4153, together with not addressing any NTDS interface requirements, appears to ignore the most likely situation that NTDS parallel interfaces will still be in active use for several more decades and will need to be connected into a SITACS system. This approach precludes the consideration of fiber optics.

The plan appears to say that a single bus is required for the total combat system. The architecture of a bus system should not be fixed as implied by the plan. The need is to define a single type or limited number of types of bus for use as parts of the combat system data network, which must be amenable to tailoring by the combat system engineers to the desired combat system architecture for each specific application. The goal of the DBSWG is to provide a new tool that will permit the DDGX Combat System Engineering Agent (CSEA) or element designer to obtain better life-cycle cost, survivability, and availability by using improved technology than can be obtained by relying solely on traditional point-to-point wiring.

It is up to the element designer and combat system integrator to design the data network. This should be done by using the most appropriate combination of techniques. In the DDGX, this combination will undoubtedly include data buses, STANAG 4153, switches, and MIL-STD-1397 interfaces, as well as appropriate operating system and application program constructs. In addition, the data bus standard (MIL-STD-1553B) currently in use in avionic systems cannot be ignored. Experience gained from the use of that bus should be applied to ship combat systems. One possibility, using MIL-STD-1553B, is the replication of buses to provide the required bandwidth. A bus system is not intended to be a transparent replacement for point-to-point wiring. Thus a trade-off in capabilities is expected. To require transparency would vitiate taking full advantage of a data bus.

The existing efforts in the commercial sector (e.g., ISO reference model, IEEE local network standards efforts) have been ignored. A method for involving Navy acquisicion managers and Navy-oriented industry is missing. Such involvement is critical to the usefulness and acceptance of any tactical communications specification or standard. The GFE approach is not presented with any justification. It may not even be desirable when compared with the embedded CFE terminal. The schedule as presented does not permit any genuine industry or user interaction in the design of the data bus, but permits only a rubber stamp of the SEA-61 design. In fact, the GFE approach specified for the external terminal will probably not meet the schedule required for DDGX.

Without some common reference mode (e.g., ISO model) and all of its attendant definition, it is difficult to understand the SITACS plan (e.g., terms like "trunk" protocol). Typically, there are "protocols" and there are "interfaces." Phrases like "interface protocols" require definition. The plan seems to be an argument against the use of a data bus rather than a plan for developing a data bus specification. On the basis of the limited technical details on SITACS presented, it appears to require a lot more cable than a bus, because of its switching nodes. It does not seem to allow "receive selection" philosophy.

A combat system element is a collection of devices. These may include sensors, computers, and controlled devices. It is unclear whether the SITACS network is to be used inside or between elements. Does it include internal data paths within a computer? The plan proposes a "standard information-transfer system architecture," which implies the basic design of all information transfer within the combat system, including voice, very-high-bandwidth radar data, and intercomputer data. However, the plan limits itself to intercomputer and other digital data transfer only.

The NAVSEA 06D plan does not *a priori* restrict itself to one architecture, but may evolve to a particular architecture, perhaps even SITACS. The intent of the NAVSEA 06D plan is to supply a tool that can be used with other tools (e.g., STANAG 4153, MIL-STD-1553B, IVCS, SDMS, MIL-STD-1397 Type A) by the Combat System Engineering Agent (CSEA) and other system designers to develop the DDGX information network.

APPENDIX H

FIRMS SUBMITTING LETTERS OF INTEREST IN DATA BUS PRODUCIBILITY STUDIES

This appendix lists the 41 firms responding to an announcement in the Commerce Business Daily on 11 December 1980 notifying industry of the Navy's intention to perform data bus producibility studies.

FIRMS SUBMITTING LETTERS OF INTEREST IN

DATA BUS PRODUCIBILITY STUDIES

Advanced Computer Techniques Corporation
437 Madison Avenue
New York, New York 10022
Attn: George Finckenor

Advanced Technology, Inc.
7923 Jones Branch Drive
Suite 500
McLean, VA 22102
Attn: Raymond W. Hine

American Computer and Electronics Corp.
Two Professional Drive
Suite 242
Gaithersburg, MD 20760
Attn: Kim E. Richeson

Applied Technology
A Division of Itek Corporation
1901 N. Moore Street
Suite 908
Arlington, VA 22209
Attn: James M. Finley

Bolt Beranek and Newman Inc.
50 Moulton Street
Cambridge, MA 02138
Attn: Joseph B. Walters, Jr.

Computer Sciences Corporation
Defense Systems Division
304 West Route 38, Box N
Moorestown, NJ 08057
Attn: Carl J. Vesper

Data Systems Analysts, Inc.
10400 Eaton Place
Suite 201
Fairfax, VA 22030
Attn: Robert J. Cunius

EG&G Washington Analytical Services
Center, Inc.
2150 Fields Road
Rockville, MD 20850
Attn: George L. Bill

E-Systems, Inc.
Melpar Division
7700 Arlington Boulevard
Falls Church, VA 22046
Attn: Mr. C. C. Fritsche
(Code E5/CD-6805)

Effects Technology, Inc.
A Subsidiary of Flow General Inc.
5383 Hollister Avenue
Santa Barbara, CA 93111
Attn: Carole A. Bryant

FMC Corporation
Northern Ordnance Division
4800 East River Road
Minneapolis, MN 55421
Attn: Larry A. Meyer

W. W. Gaertner
205 Saddle Hill Road
Stamford, CN 06903
Attn: Dr. W. W. Gaertner

General Electric Company
Electronics Laboratory
P.O. Box 4840
Syracuse, NY 13221
Attn: Eldon D. Fox (EP 3-103)

General Research Corporation
Southern Division
307 Wynn Drive
Huntsville, AL 35805
Attn: Dr. Glenn Cox

Georgia Tech Research Institute
Code SS-10106
Georgia Institute of Technology
Atlanta, GA 30332
Attn: Donald J. Grace

Grumman Aerospace Corporation
Engineering Development Center
Bethpage, NY 11714
Attn: Christopher J. Witt

HDR Systems, Inc.
8404 Indian Hills Drive
Omaha, Nebraska 68114
Attn: John F. Eagleton

Harris Corporation
Government Communications Systems Division
P.O. Box 37
Melbourne, FL 32901
Attn: R. H. Painter

JMS Corporation
15912 Shady Grove Road
Gaithersburg, MD 20760
Attn: Jeffry Yeh

International Business Machines Corporation
Federal Systems Division
Route 17C Tioga County
Owego, NY 13827
Attn: Frank J. Romanelli

International Computing Company
4330 East-West Highway
Bethesda, Maryland 20014
Attn: John Kenyon

International Telephone and Telegraph Corporation
Defense Communications Division
Telecommunications and Electronics Group-North America
492 River Road
Nutley, NJ 07110
Attn: Murray Weinberg

International Telephone and Telegraph Corporation
Electro-Optical Products Division
7635 Plantation Road
Roanoke, VA 24019
Attn: Jack B. Freeman

JRS Industries, Inc.
11722 Sorrento Valley Road
San Diego, CA 92121
Attn: Erwin H. Warshawsky

Lockheed Electronics Company, Inc.
U.S. Highway 22
Plainfield, NY 07061
Attn: Walt J. Littles

Magnavox Data Systems, Inc.
2980 Telestar Court
Falls Church, VA 22042
Attn: Jerry D. Elliott

Network Analysis Corporation
301 Tower Building
Vienna, VA 22180
Attn: Patty Roepken

Oakwood Electronic Systems, Inc.
2424 Far Hills Avenue
Dayton, Ohio 45419
Attn: Clifford W. Kruer

RCA Corporation
Government Systems Division
Missile and Surface Radar
Borton Landing and Marine Highway
Moorestown, NJ 08057
Attn: Edward C. Capone (M/S 127-3

Raytheon Company
Equipment Division
Boston Post Road
Wayland, MA 01778
Attn: Shay D. Assad

Rockwell International
Defense Electronics Operations
Autonetics Marine Systems Divisio
Shipboard Information Systems
3370 Miraloma Avenue
P.O. Box 4921
Anaheim, CA 92803
Attn: R. G. Titus

Gordon S. Rosen Assoc. Inc.
Pomona Professional Plaza
Route 45
Pomona, NY 10970
Attn: M. B. Fannon

AD-A109 607 ARINC RESEARCH CORP ANNAPOLIS MD F/G 9/2
TECHNICAL SUPRORT TO DDGX DATA BUS SPECIFICATION WORKING GROUP.(U)
OCT 81 C LACIJAN, D KOBER N00173-79-C-0463
UNCLASSIFIED 1687-01-1-2561 NL

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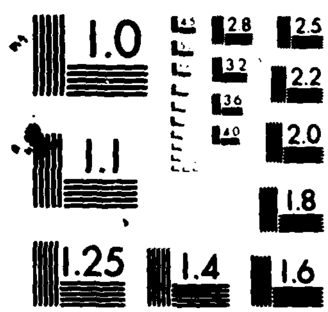

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SEMCOR, Inc.
2341 Jefferson Davis Highway
Arlington, VA 22202
Attn: Lee Ashman

Shaker Research Corporation
Northway 10 Executive Park
Ballston Lake, NY 12019
Attn: Lawrence J. Lagace

Sperry Univac
Defense Systems Division
P.O. Box 3525
St. Paul, MN 55165
Attn: D. G. Schaefer (M/S U1J13)

Teledyne Systems Company
19601 Nordhoff Street
Northridge, CA 91324
Attn: Joe Frazell

Telephonics Corporation
770 Park Avenue
Huntington, NY 11743
Attn: Harris D. Graber

Triad Microsystems, Inc.
555 Sparkman Drive
Suite 636
Huntsville, AL 35805
Attn: Alan D. Sherer

Update Research & Development
P.O. Box 831
Glendora, CA 91740
Attn: Dr. Don M. Yee

Walden Management Services, Inc.
A Subsidiary of KMS Industries, Inc.
3980 Quebec Street
Denver, CO 80207
Attn: Ron R. Brennan

Wood-Ivey Systems Corporation
3535 Forsyth Road
Orlando, FL 32807
Attn: H. Reese Ivey